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Paints and Their Environmental Impacts on Human Health in The U.A.E

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Paints and Their Environmental Impact on Human Health in the U.A.E

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To my little brother Eng/ Ahmed Al-Ameri and all those whom really Love & Care about me and want to see me the best always

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Masara Y. Al-Ameri

Paints and Their Environmental Impacts on Human Health in the U.A.E

ABSTRACT

This thesis records the findings of a research program related to "Paints and Their Environmental Impacts on Human Health in the U.A.E". The study recommends attempt to find out what paint types are of a less harmful influence on human health within different building types in United Arab Emirates due to environmental conditions.

According to Larry W. Canter (1997) "Environmental Impact Assessment" can be defined as "the systematic identification and evaluation of the potential impact (effects) of proposed projects, plans, programs, or legislative actions relative to the physical- chemical, biological, cultural, and socioeconomic components of the total environment. The primary purpose of the EIA process is to encourage the consideration of the environment in planning and decision making and to ultimately arrive at actions which are more environmentally compatible."

It is believed that finishing materials have had a very harmful impact on human health. For this reason this belief was chosen to become an aim of our thesis study. The Research study has attempted to identify main types of used finishing paints, their impacts on various building types and users. For this purpose two types of buildings were chosen, on which the study was to be applied: Educational Buildings and Low Cost Housing.

The comprehensive review of literature focuses upon various diseases and systems apparent on building users before and after paint application is carried out in any given space or building in the Emirate of Abu Dhabi. But in order to make the research more effective, a concentrated study was done on three particular chosen cities which are of the most populations: Abu Dhabi, Baniyas and Shahama.

On the basis of the research analysis of both experimental, field works, as well as literature analysis; the study concludes that there is a misunderstanding in the community that water base paints are of less harm to human health in the United Arab Emirates; as is believed and proven in international studies. So this study started out with the aim of proving this theory; but a quite astonishing and unexpected result was achieved instead. It is important to put into prescription that No previous studies in the U.A.E or any other Arab country region have been done in this field therefore information was quite scarce and based on theory and mouth talk.

To imply the results of this analytic research into the community and especially into buildings constructed under the regulations of government departments such as the works department in Abu Dhabi, the following is mostly recommended:

1. Different paint types are required for different building types of buildings with relation to the city of location and environmental factors that are advised to be considered.
2. It has been noticed from study results that paint materials are not the only factor playing a role in effecting human health and comfort of internal spaces. There are other factors effecting the hazardous health symptoms and diseases that appear on users in different building types such as: users suffering of them even before a paint job is done, pollution, climate, population, environment of space, temperature, humidity ventilation and many other factors as well.
3. In case of educational buildings it was found from user response analysis that it is most advised to use acrylic based paint in coastal and semi coastal regions of the country (ex. Abu Dhabi and Shahama cities), while water base paints were best used in desert regions (like Baniyas city).
4. In case of residential buildings it advised to be suitable to use acrylic paint in coastal and desert regions (ex. Abu Dhabi and Baniyas). Water base paint in semi coastal regions such as city of Shahama is suggested to be more appropriate
5. Amazing result were achieved from test samples, there are hundreds of paint trade marks available with a broad range of paint types and colors available on the market, but the fact remains that they are all similar materials with slight difference in appearance or property.
6. Different test methods and sample techniques have been able to reveal the fact that there is no such thing as 100% environmentally friendly or hazard-free paints. But we can say there are less harmful paints on human health or of a less environmental impact.
7. It is wisely advised that paint manufacturers are to be notified of study concluded results in hope that such materials will be developed in respect to country health regulations and environmental aspects taken into in consideration during manufacturing process of any paint type.
8. It is suggested that the manufacturing of paints is to be in association with environmental regulations stated specifically with the U.A.E. environment (or similar environments) with relation to environment associations or groups examples of the ERWDA (environmental research and wild life development agency) or friends of the environment group.

9. This section gives consideration to recommendations and suggestions of how study obtained results may be helpful in the community and especially into buildings constructed under the regulations of local government departments or ministries in the emirate or also on the level of the country such as the works department in Abu Dhabi.
10. it is suggested that further more detailed can be carried out on paint materials and their types (or other building materials) with consideration to environmental aspects. , to provide more accurate and most safe and healthy space environment for various building envelopes. It is advised that this is carried out with aid and coordination of government authorities and environmental associations such as: friends of environment association, Environmental Research and Wildlife Development Agency (ERWDA) ...etc.
11. it may be wise to encourage the carry out of further studies on other factors that might have effect on how paint materials may enhance hazardous effects of different building users should thoroughly and carefully be done with aid of specialists in this field both on the local and international levels. Examples of these studies are to be related to climate (temperature, location, urban activities of the city, building use, ventilation, etc.). these encouragement can be in form of financial grants, scholarships awards etc.
12. it may be very effective if a material standard specification encyclopedia be written out related specifically with United Arab Emirates environment and health information taken into consideration, similar to standard specifications used on international level..
13. It is recommended that a material standard specification encyclopedia be written out related specifically with United Arab Emirates environment and health information taken into consideration, similar to standard specifications used on international level.
14. it is suggested that Urban development plans are to be according to suitable geographical distribution and design stage with consideration to suitable material selection to use with respect to building location and activity type.
15. Users are to be aware of first aid procedure when dealing with any paint type and it should be handed out by manufacturer with assurance of government authorities.
16. These suggestions can be done on 3 levels of the community: local government authorities and environmental organizations & associations, population of the community, paint manufacturers.
    - Government authorities in coordination with environmental associations and organizations:

    1. It is seen to be a necessity for Government authorities and local departments to be highly aware and careful that paints used in any building type are according to health specifications of the city and building type before building permits are released. It's

also advised that this takes place whether or not these projects are executed for the government or private. This is expected to be done in coordination with environmental associations and associations on the local and international level.

2. it is highly advised that site engineers and other concerned engineers are to be traied to raise their level of knowledge in building materials (including paints and their types) and their effects on human health. This may enlighten them on the importance of their role of keeping things into perspective of human health and the environment.

- Manufacturers, contractors and building material suppliers:

1. It's believed that enhancement of fines on contractors, suppliers and manufacturers who don't follow government paint material (or any other building material) specifications approved and standardized by local or higher government authorities such as from government departments, ministries or environmental organizations...etc.
2. it is believed to be highly effective that fines are to be enhanced on paint manufacturers, suppliers or contractors using paints (or any other building materials) that are without written information on hazards :
    a. Flammability/ Combustibility:
    b. Solvent toxicity:
    c. Safe use of: Inhalation, Ingestion, Skin Contact, Storage instructions and regulations.
    d. Protecting The Environment By Good Formulation
    e. Toxicity And Environmental Pollution:
3. it is suggested that all paint materials (or any other building materials) not following legal authorized specifications implied by local authorities and in coordination with health and environment groups and foundations are to be banned from construction use immediately. But this recommended to be done only after warning.

- Community population:

1. Encourage user awareness on paint finishing materials and how to choose them according to design requirements and building use with other concerned aspects in consideration and not select just according to taste and desire or economic reasons or factors.
2. It is seen to be important that user awareness may be required of first aid procedure when dealing with any paint type and it should be handed out by manufacturer with assurance of government authorities.

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Chapter 1:

Introduction

1.1 Introduction To The Study:

In the past few decades a large increase in allergic diseases has spread and been observed and recorded in the U.A.E region. The types of finishing materials being used in construction of many buildings is one of the main causes of this rapid increase in diseases appearing in the community. Of course it must be noted that there are other factors affecting the result of these used finishing materials. But here we will try to concentrate on the internal material factors it itself and not the external ones though they might sometimes be of a great influence but these maybe studied in further future research or studies.

Not many studies have been applied on the Gulf Region with relation to human health and environmental factors and hardly any have been done on the UAE in particular. This research may be first of it is kind and one that may become of great use if applied in further studies that shall be carried out. It will hopefully be a great leap in the field of finishing materials and how they affect humans in a direct and indirect way.

The study intends to take U.A.E as an example country for the gulf region that almost faces the same environmental and climate conditions. It will particularly deal with the Emirate of Abu Dhabi's three most populated cities: Abu Dhabi, Baniyas and Shahama.

1.1.1 Increasing Appearance Of Allergic Symptoms And Diseases:

Through the following chapters of this thesis study it has been proved that allergic symptoms and diseases in the emirate of Abu Dhabi have been increasing in the past two decades. Part of the responsibility can be related to construction and standard used materials that have been used in executing private, public and government buildings which have witnessed a large development and wide spread in past twenty five years.

The study has concentrated on public government executed buildings (low cost housing, educational buildings). These buildings like other government executed buildings are built according to a standard material coded booklet, which includes paint as an approved protective as well as decorative finishing material by local government departments. Paints with their various types and required finishing appearance are all coded and priced according to square meters. From here it is known that the most commonly used paint trade marks are (National, Khaleej, Jotun, and Burger). All approved paints are from local paint companies even if they do represent foreign companies. It is also necessary to state here, that this material as well as other standard building materials approved and mentioned in material booklet have not been based on scientific research studies but generally on common use experience and practice. Therefore many of them may not suit their use or adapt to local environment or climate in which they are being applied.

A fact about these paints, though locally manufactured, is that they follow standards of their original foreign countries, which in most cases have a totally different environment and climate. There was no standard paint description or specifications found during data collection stage of thesis for any Arab country or United Arab Emirates in particular. Therefore it is believed that the difference of climate and environment between those cold foreign countries (original manufacturer country) and our hot humid countries has caused these paints to react differently than proposed or expected. Some of these manufacturers have started to notice effect of environmental climate differences on their products which effected health of the end users[1]. For this reason they have introduced new products in the market which they claim to be healthy and friendly to environment. This concern of the manufactures was based on increasing number of complaints from users and government health sources concerning increase of dermal and respiratory diseases as well as requirements of repeated maintenance.

1.1.2 The Geographical Distribution Of Various Urban Activities

The U.A.E like any other urban country in the world has a certain urban planning development plan. This plan distributes economic, educational, health, sports and residential activities according to the suitable geographical distribution required for such different activities.

Abu Dhabi (Figure 1.1) is the largest of all seven emirates comprising the United Arab Emirates, with an area of 87,340 sq.m, which is equivalent to 86.7 % of the country's total area, excluding the islands. The city of Abu Dhabi is the capital of the emirate and also the federal capital of the country. H.H. Sheikh Bayed bin Sultan Al Nahyan, President of the UAE, resides in Abu Dhabi city. The Parliament buildings, most of the federal ministries and Institutions are located here, as are the foreign Embassies, the state broadcasting facilities, and most of the oil companies. Major Infrastructural facilities include Port Zayed, Abu Dhabi International and extensive cultural, sport and leisure centers, together with the wonderfully engineered Abu Dhabi Corniche which offers many kilometers of risk-free walking, cycling, jogging and roller-blading along the seashore of Abu Dhabi Island. Architecturally speaking the city is also a fascinating place where older buildings sit comfortably in the shade of futuristic modern skyscrapers.

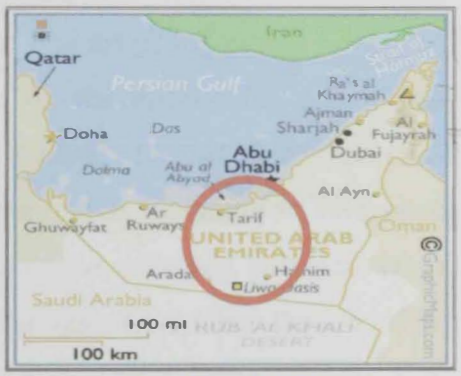


Figure 1.1 U.A.E Map and location of Abu Dhabi city

Where as less activities are found in the rural cities such as Shahama and Baniyas. Though they include educational, health and some commercial services, they are mainly based to

[1] Example of these paints is (jotun Fenomastic gold, HB Pengaurd) which are stated to be environmentally and health hazard free paints

be residential cities in which low cost houses have been established and increasing in both number and during past few decades. Where as on the other hand industrial cities such as Musafah consist of emirates industrial factories and service Providing stations (mechanical, carpentry, ironmongery ...etc.)

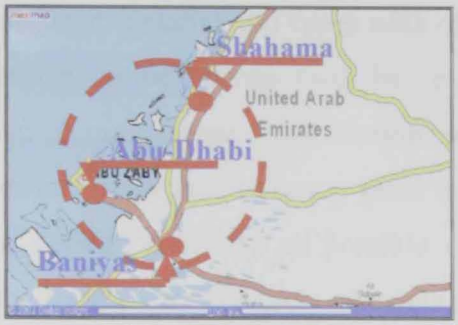


Figure 1.2 Emirate Of Abu Dhabi and Location Of Study Cities

1.2 The Aim And Objectives Of The Study:

The main aim of this study is to find out the most suitable or less harmful paint type on human health for occupants in the UAE in particular and gulf region in general. This will be related to material ingredients, application methods and environmental impacts on human health in the UAE. It's important to state here that the case studies will be carried out on the emirate of Abu Dhabi as a sample of similar environments and the cities picked from it will represent similar coastal (Abu Dhabi), semi-coastal (Shahama) and desert regions (Baniyas).

The conclusion and recommendations will be based on the information and lessons obtained from similar studies drawn from a literature review, to establish theoretical requirements and an analysis of the existing circumstances in the region, including an assessment of the main problems and diseases facing the population due to the wide and common use of paints as the main finishing materials in almost all type of buildings. To achieve the aim of the study, seven related objectives would be identified:

- The main ingredients and differences between the most commonly used paints applied in constructed buildings.
- The most common diseases apparent within the UAE population, particularly within the Emirate of Abu Dhabi
- To reach a certain conclusion on the less and most harmless paint type that should be applied in buildings, with aid of literature study, user questionnaire analysis and experimental test result analysis.
- Studying the importance of paints as a main finish of building materials.
- Studying the standard specifications of paints and their toxic content.
- The impact of paints on human health within hot arid regions (Case Study from UAE)
- Assessment methods of paints and their environmental impacts on human Health.

1.3 The Research Methodology

Once the field area to be studied was identified, it was necessary to select an appropriate research approach and to design a comprehensive outline with which the aim and objectives of the study can be achieved. The study research is divided into three main phases. Theoretical back ground and literature reviews on paint material and types with respect to: application functions, methodology, human health aspect considerations (will be reviewed), user information data collection analysis with the help of questionnaire distribution, experimental testing results and analysis with the aid of computer programs mainly power point and excel.

- The first phase assess and defines precisely as possible causes of the problem from a scientific point of view trying to relate it to impacts of paints on human health. Where as the second phase of study presents a better theoretical understanding of the major issues. This phase is done with contribution to study related problems; identification and development in this case by using different end user feed back information answers given to distributed questionnaires. In there turn these answers have been analyzed and graphical chart studies have been established. The third and last phase will be responsible of translating theoretical understanding and lessons learned from the literature review and comparing them with experimental lab tests on samples done for various types of paints. Later a comparison will be done and conclusions will hopefully be reached. This approach is adopted from Etzeoni (1967) as a realistic approach for such problems with partial changes so that it would adapt to my study needs and required aims. It shall be carried out through the following stages as stated in (figure 1. 3) below.
  - ***Stage 1:*** Investigation of the role of the works department as a governmental department directly responsible for the construction of public government buildings: health, educational, government offices, low cost residential unit is .. etc.
  - ***Stage 2:*** A literature review to disclose the lessons that may be drawn from experiences in similar study area with similar problems, and to provide a theoretical basis for the Evaluation of alternative finishing materials or paint types.
  - ***Stage 3:*** Application of the literature review outcome to the case study area
  - ***Stage 4:*** Identification of the key issues of the study, on which proposals and Recommendations will be based on.

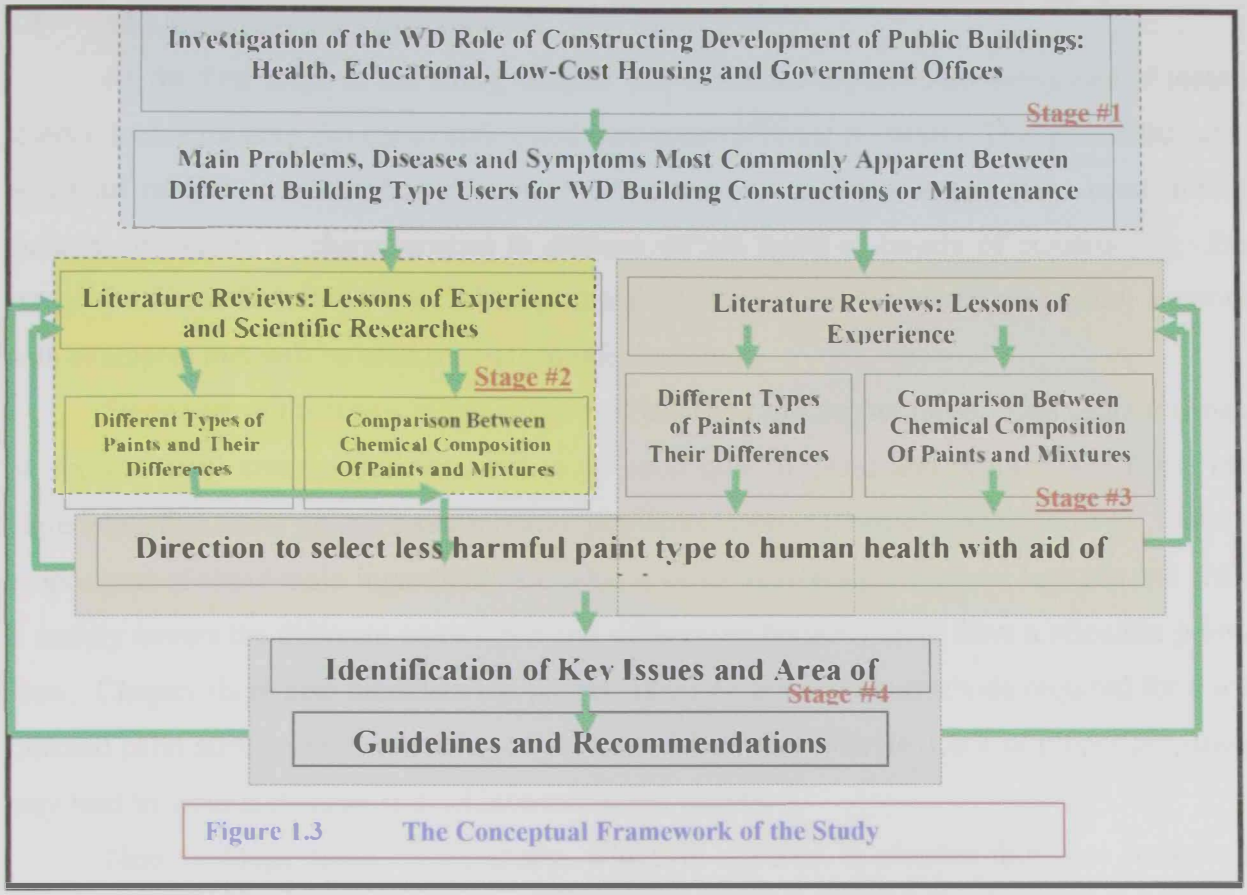


Figure 1.3 The Conceptual Framework of the Study

1.4 The Hypothesis Underlying The Research

The research programme was developed to examine the basic hypothesis which develops the hypothesis that is based upon an initial analysis of the existing circumstances and assessment of the evident problems, focusing in particular on paints and their environmental impact on human health in the UAE in general and the emirate of Abu Dhabi in particular. The research study identifies a number of fundamental questions in which the programmed study and design approach will attempt to answer as much as possible for such a study. These questions are:

1. What are the different types of paints used in government constructed buildings?
2. How do these important finishing materials differ from a literature scientific point of view?
3. How was the empirical work results gained, analyzed and what did they conclude to?
4. The importance of a comparison between literature data collection and empirical work. questionnaire distribution and data analysis backed up with experimental lab tests and analysis of results.
5. To what extent may this study be adopted by political authorities and applied?
6. What practical suggestions can be made to improve internal environmental spaces and public knowledge for different building types?

1.5 The Structure Of The Research

As the first stage of the study, chapter two discusses the different categories of material science including both the construction and non-constructional materials. This part is thought to be useful in understanding how materials differ and how different applications need different material properties or characteristics to achieve certain goals or targets of construction. Each category covers: definition, brief history, chemical structure and material properties, supported with examples that will be used to confirm information.

Stage two of the thesis report is covered basically in Chapter three. This chapter is based on the chemical composition that makes up each type of paint and proportions of the main ingredients that make up any paint mixture: pigments, solvents, vehicles and additives. Different proportions of these main ingredients are what give us different paint types, textures and colors. It mainly covers the different paint types and differences between them from a scientific point of view. Chapter three also discusses the proper substrate preparation methods required for a well-finished paint surface each according to the material of the substrate. Lack of proper preparation may lead to serious damage and achieve undesired results.

Next is Stage three of the study, which is covered in chapter four that includes all empirical work carried out. This work again has been divided into two main parts. First the questionnaire distribution and data collection analysis which is distributed in bar charts with numerical figures to make them more sensed and of a logical understanding. As for the second part, results are obtained from testing different paint samples in the laboratory to find reasonable explanations to questionnaire analysis results. This part of the study is the core of the study discussed in chapter three and four. It is from this chapter all work conclusions will be stated and declared and from which the result explanations will be based and hypothesis confirmed.

Finally but not least stage four, declares all results obtained through out this research study. It gives a review of whole study by re-stating the Identification of Key Issues and Area of Decisions. It will also give Guidelines and Recommendations to the most suitable Directions to select less harmful paint type to human health with aid of applying experience to the study. Future research work in such an area is also suggested in this chapter.

Chapter 2:

Material Science

2.1 Introduction:

Paints are polymeric materials that are one of the five main categories of material science. The world of material science is a wide and complex one. This is related to the fact that there are various material types available, whether they are natural or artificial, structural or non-constructional, etc. This science deals with both fundamentals of structure of the materials and their classifications, in addition to the classification of the types of materials: *Metals, Ceramics and Glasses, Composites, Polymers and Semi-Conductor Materials*

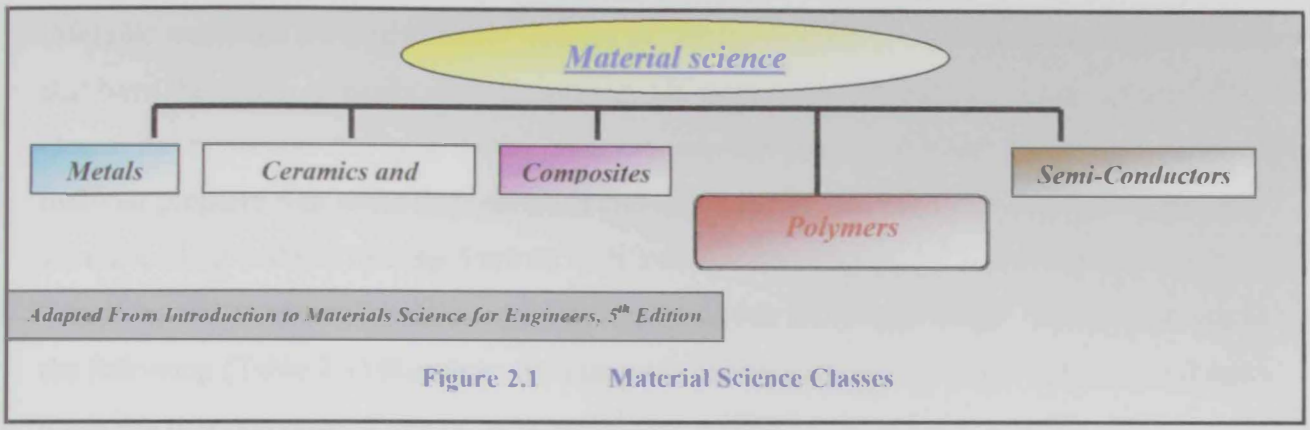


Figure 2.1 Material Science Classes

This chapter is dedicated to the discussion of categories of the material world. This was done with belief of giving better understanding and guidance to the reader on how and where paints branch off from. But since only the first four types of materials are related to the finishing materials field used in the construction industry the semi conductor category will be emitted. Certain emphasis will be put on the polymer materials category, since they are the mother of the main core topic of this thesis presentation, which shall be taken particularly on polymeric paint materials.

Each of these material categories will be given a brief definition, a brief history, description of the nature of chemical structure and material properties, supported with examples that will be used to confirm information.

But before that it is essential to get a few main issues clear to ease understanding of the major concepts of this chapter. Structural materials are "materials that have the ability to undergo repeated severe loading without fracture". These materials are usually used for within the construction of the building main structures. Examples of these materials are steel and concrete. Where as non-structural ones are those "materials that can not be used in the main building structure to undergo loads". But still they do have a great role in protecting the structure of buildings either from the inside or outside. Other than just being protective materials they are also extremely used for decorative purposes. Paints are the best examples for such materials.

2.2 Metals:

There is a wide range of ferrous and non-ferrous metals and their alloys being used within construction. But those whom lead in construction are irons, steel, aluminum, copper, lead and zinc. Though metals need a large amount of energy to put into their production from raw materials, they are still the most used. This is related to their long life spans and ability to be recycled.

2.2.1 Definition:

Metallic materials are scientifically defined as "strong (metallic) versatile construction materials that have the ability to easily undergo extensively permanent deformation without fracture". One of its' important and most useful properties are that they are ductile. Ductility is "a metallic material property that states that materials can easily deform and undergo extensive repeated severe loading without causing fracture". It's due to this property of metal ductility which assets in permitting small amounts of yielding to sudden and severe loads. The shaded area in the following (Table 2.1) illustrates the bases of various engineering alloys (Alloys are metallic materials that compose of one or more metal elements).

Table 2.1 Periodical Table

IA																	O
1 H	IIA							VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	2 He
3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	IIIB	IVB	VB	VIB	VIIB							13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn		31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd		49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg		81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac																

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

Adapted From Introduction to Materials Science for Engineers, 5th Edition

2.2.2 History:

Ferrous metals have been known ever since the Iron Age that was about 1200bc in making weapons. Steel is a recently used material that has only become available in large quantities in the end of the last century. The carbon content alloy has a great influence on the physical properties that are related to the microstructure of it is crystals.

2.2.3 General Properties:

The atomic bonding of metals, have their affect on their properties. In metals, the outer valence electrons are shared among all atoms, and are free to travel everywhere. Since electrons

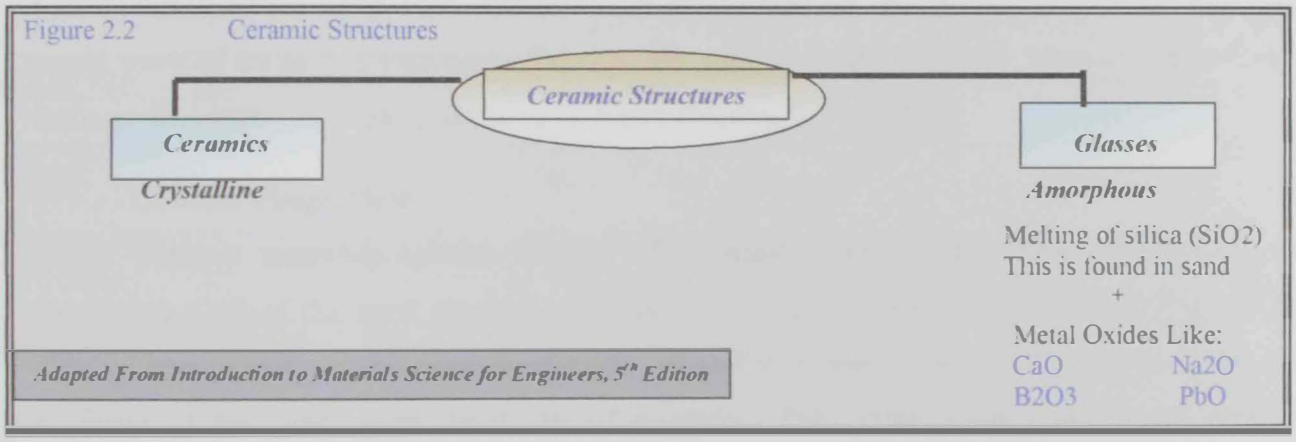
conduct heat and electricity, metals make good cooking pans and electrical wires. Adding other metals to alloy metallic elements or materials can affect the density, strength, fracture toughness, plastic deformation, electrical conductivity and environmental degradation. For example, adding a small amount of iron to aluminum will make it stronger. Also, adding some chromium to steel will slow the rusting process but make it more brittle. Brittleness is a phenomenon or property that is related with materials that cannot undergo severe pressure without fracture occurring in them. This nature is mainly related to ceramic materials

Metals are elements that generally have good electrical and thermal conductivity. Many metals have high strength, high stiffness, and have good ductility. Some metals, such as iron, cobalt and nickel are magnetic. At extremely low temperatures, some metals and intermetallic compounds become superconductors.

2.3 Ceramics and Glasses:

These engineering materials Ceramics and glass, though partially different, they are also both very similar at the same time. The main difference is in their properties and appearance. This in it is turn is due to their internal microstructure and chemical bonds between their molecules. Therefore it has been found best to study each group of these engineering construction materials separately Therefore, they can be divided into main categories with relation to internal microstructure as shown below in (figure 2.2).

Figure 2.2 Ceramic Structures



2.3.1 Ceramics:

The majority of raw materials used by the ceramic industry are the oxides of metals. The three metals, which have been the main stays of the industry for many years, are *clay* (hydrated alumni silicates and are the end product of the weathering of feldspathic rock. The most important clay mineral is Kaolinite, which has the composition AL2O3 - 2SiO2 - 2H2O), *flint* (is a form of silicon dioxide (SiO2) usually produced from quartzite, sand or rock, and *feldspar* (a broad, generic name applied to a group of alkali-aluminous silicates. Most feldspar, however, are combinations of these two types. Feldspar is used and known as a "flux" in the ceramic

industry). These are the major materials contained in what is sometimes referred to in the industry as "classical ceramic bodies". The high chemical durability of the great majority of ceramics makes them resistant to almost all acids, alkalis, and organic solvents. Of further importance is the fact that ceramic materials are not affected by oxygen. These materials are usually of a hard brittle nature and the bonding is ionic, covalent or has mixed ionic, covalent characteristics.

A Definition:

Ceramics are inorganic materials that have non-metallic properties and are usually processed at a high temperature at some time during their manufacture. They are defined to be chemically stable, opaque, materials made up of one of 5 non-metallic elements (Carbon C, Nitrogen N, Oxygen O, Phosphate P And Sulfur S) as shown on (table 2.1). These materials have a high a resistance to high temperatures. They are also known under the common name of "pottery products" and their name is derived from the Greek word "keramos" meaning "burnt clay".

B History:

The history of ceramic tiles dates back as far as the fourth millenium BC where in Egypt tiles were used to decorate various houses. As early as 4,000 BC ceramics were also found in Mesopotamia. In the early days, the tiles were hand-made, formed and hand-painted, thus each was a work of art in it is own right. Ceramic tile was used almost everywhere-on walls, floors, ceilings, fireplaces, in murals, and as an exterior cladding on buildings.

C General Properties:

Ceramic materials have a number of outstanding properties, which determine their usefulness. One of the most unusual of these is their great durability. This durability can be divided into three types: ***Chemical, Mechanical and Thermal***. The strength and hardness are evidence of the mechanical durability of ceramics. The compressive strengths of ceramic materials are extremely high. This hardness makes ceramic materials very resistant to abrasion. It is this property, which makes them useful for floors, and for the grinding of metals and other materials. Their high melting temperature, most ceramics have the ability to with stand high temperatures. This is why they are useful in the production of all types of heat-containing equipment such as kilns for the ceramic industry, and such products as the inner linings of fireplaces and home heating furnaces. Many ceramics are good electrical and thermal insulators.

These materials have advantage of low density, high strength, stiffness, and hardness; wear resistance, and corrosion resistance. But still, like all materials ceramics also have their restrictions, to their applications, due to their brittle material nature. Their brittleness tends to

make it almost impossible for them to undergo severe pressure that will only cause their fracture and material failure. For this reason ceramic materials are usually illuminated from many constructional applications.

2.3.2 Glasses

These materials are the second group of the ceramic family. For most commercial glass families, silica sand is the main ingredient, however to obtain melting and other flexibility properties, additions are made especially that of other oxides. Glasses are classified into groups depending on their constituents and the properties, advantages. Applications and economics so that glasses may be specified and selected in the same way as metals and alloys.

A Definition:

They are defined as "an inorganic product of fusion, which has cooled to a rigid condition without crystallizing." In other words they are "super cooled liquids", that are known to have a non-crystalline (amorphous structure) that gives an increase to it is transparency. In its' turn this is related to glasses dual nature of combining between properties of a rigid solid with some of the characteristics of liquids, which give rise to it is versatility.

B History:

No one knows exactly when or where glass was first made. But it appears that the Egyptians and perhaps the Phoenicians have produced glasses as far back as the second millennium B.C. Yet evidently it originated in Mesopotamia, where pieces of well-made glass have been found, believed to be dated way back from the third millennium BC. However, modern glass is manufactured from silica (sand 70-74%), sodium oxide (12-16%), calcium oxide (5-12%), and magnesium (2-5%). In addition to small quantities of aluminum, iron and potassium oxides. An addition of 25% broken glass or cullet to furnace mix helps in accelerating the melting process and recycles production waste.

C General Properties:

There are many different physical and chemical properties found in commercial glasses related to the broad and various types of glass available to designers and of special compositions, which can be formulated for special purposes, or need of special operating conditions. The physical properties of glass are primarily determined by it is chemical composition. Glasses may be considered in three main groups. ***Soda-lime-silica glasses, lead glasses, Boro-silicate glasses.***

Soda-lime-silica glasses constitute the largest volume of commercial glasses, suited to automatic forming methods, available in flat form produced from sheet drawing, float and rolling processes, as containers produced by blowing, molding, and pressing. While Lead ***Glasses*** are

mainly used for optical components, for radiation shielding, for decorative applications and for a range of technical glasses and it can be processed by a variety of methods but mainly by extrusion, casting, pressing and molding.

Glass materials commonly demonstrate the following properties: ***Viscosity, Corrosion Resistance***. Glass materials also have the advantage of having ***Optical Properties*** due to their ability to transfer light. Another of its important and noticeable properties is their ***Hardness and Abrasion Resistance.*** But still glass materials have a brittle nature which governs its weakness under tensile stress, although very strong under compression. Even though Brittleness does not prevent high strength of glass material but still it has low fracture toughness (but rather high strength when there are no flaws).

2.4 Composites:

These materials are made up of a combination of individual materials: melts, ceramics or glasses or polymeric materials. These materials can either be obtained from natural or artificial sources. Composite materials are defined to be" ***any material made from two or more materials which give a range of properties and behavior not found in individual component materials***" (Yvonne Dean, 1989). From the previous definition of these materials it is possible to conclude that there is a wide range of composite materials that can be made. But, they may be generally short listed into two main classes of constructional materials that will be discussed here: wood as a natural material and concrete as an artificial one.

2.4.1 Wood

Commercial timbers are defined as hardwoods or softwoods according to their botanical classification. Hardwoods come from broad-leafed trees. But, softwoods come from conifers, characteristically with needle shaped leaves (Arthur R. Lyons .1997). In the building industry timber is used for a wide range of purposes from rough sawn structural members to claddings, trim and highly machined joinery. The Specification of timber for each use may involve defining the particular hardwood or softwood where visual properties are required (Table 2.2).

But generally, whenever strength and durability are the key factors, timber is usually the material to be selected. Compared to other major constructional materials timber, as a renewable resource is environmentally acceptable. Trees require little energy for their conversion into usable timber. For thousands of years this natural material has always been considered to a wonderful example of a natural composite constructional for both interior and exterior applications. These materials have great mechanical properties based on their internal fiber reinforced structure (Arthur R. Lyons, 1997).

Table 2.2 Some Common Known Woods	
Soft woods	Hardwoods
Cedar	Ash
Douglas fir	Birch
Hemlock	Hickory
Pine	Maple
Redwood	Oak
Spruce	
Adapted From Yvonne Dean, 1989	

2.4.2 Concrete

As for Concrete materials they are a good example of artificial aggregate composite materials. They are extremely strong, durable materials with a porous character. Concrete is considered as a universal material of construction. The raw material for it is manufactured and may easily be available in every part of the globe. It can be made into buildings with tools ranging from a primitive shovel to a computerized precutting plant. Concrete neither burns or rots and is relatively low in cost and it can be used for every building purpose from low paving to steady structural frames to handsome exterior claddings and interior finishes. But on its' own concrete has no form or any useful tensile strength.

A Definition:

Concrete blocks are structural materials produced from mixing three basic ingredients in the concrete mix: Portland cement, Water and Aggregates. **Portland cement** is the cement and water that form a paste and act as the matrix that encloses the aggregates and bonds the aggregate particles into a rigid solid. Where as water, is needed to chemically react with the cement (hydration) and too provide workability with the concrete. On the other hand **aggregates** are sand which is the fine aggregate and Gravel or crushed stone that are the coarse aggregate in most mixes. In addition to these main ingredients certain **admixture** are used to modify the placing and curing process or the physical properties of the block. Demonstrates the types of admixtures that are available and the main aim of what they do when added they are to be added is stated in (Table 2.3). ***Add mixtures*** can be defined to be any components that are found in a concrete mixture other than aggregate, water and cement. These components help provide desirable features and properties to the end product.

Table 2.3 Admixtures		
Type	Characteristics	Example
Accelerators	Give early strength and curing to the mixture	CaCl2
Air entertainers	Reduce air-water interfacial tension to form entrapped air bubbles and increase workability and freeze-thaw durability.	Sodium lauryl sulfate
Bonding admixtures	Bond fresh to hardened concrete	Fine iron particles plus chloride
Coloring agents	Provide surface color	Inorganic pigments
Expansion admixtures	Reduce shrinkage due to formation of an expanding rust	Fine iron particles plus chloride
Gas formers	React with hydroxides to produce H2 bubbles and resulting porous (cellular) structure	Aluminum powder
Pozzolans	Silica reacts with free CaO To Produce Additional C2S hydrate, which reduces the heat of hydration.	Volcanic ash
Retards	Retard curing and prevent bonding between hardened and fresh concrete	Lignosulfonate salts
Surface hardeners	Produce abrasion-resistant and fresh concrete	Fused alumina particles
Water reducers	Increase workability	Lignosulfonate salts
Adapted from: R.Nicholls, 1976		

B History:

Concrete materials are considered to be one of the old construction materials known to mankind. Concrete was first used by the Romans over 2000 years ago. They used it in the construction of their aqueducts and roadways. This discovery was found during their quarrying limestone for mortar and accidentally discovered a silica alumina- bearing mineral which when mixed with limestone and burned produced cement that exhibited the unique property of hardening under water as well as in the air. With time this mortar not only became the preferred type for usage in all their buildings but also began to change the character of roman construction totally (Allen E. , 1990).

They used a primitive mix for their concrete. Mortar consisted of small gravel and coarse sand mixed together with hot lime and water. To reduce shrinkage, they used horsehair, much like we use polypropylene fibers today. They even unintentionally entrained the air in the mix by adding animal blood. That process created small air bubbles in concrete, making the mix more durable today; concrete is finding more inventive uses especially in field of residential construction and works of art (Arthur R. Lyons, 1997).

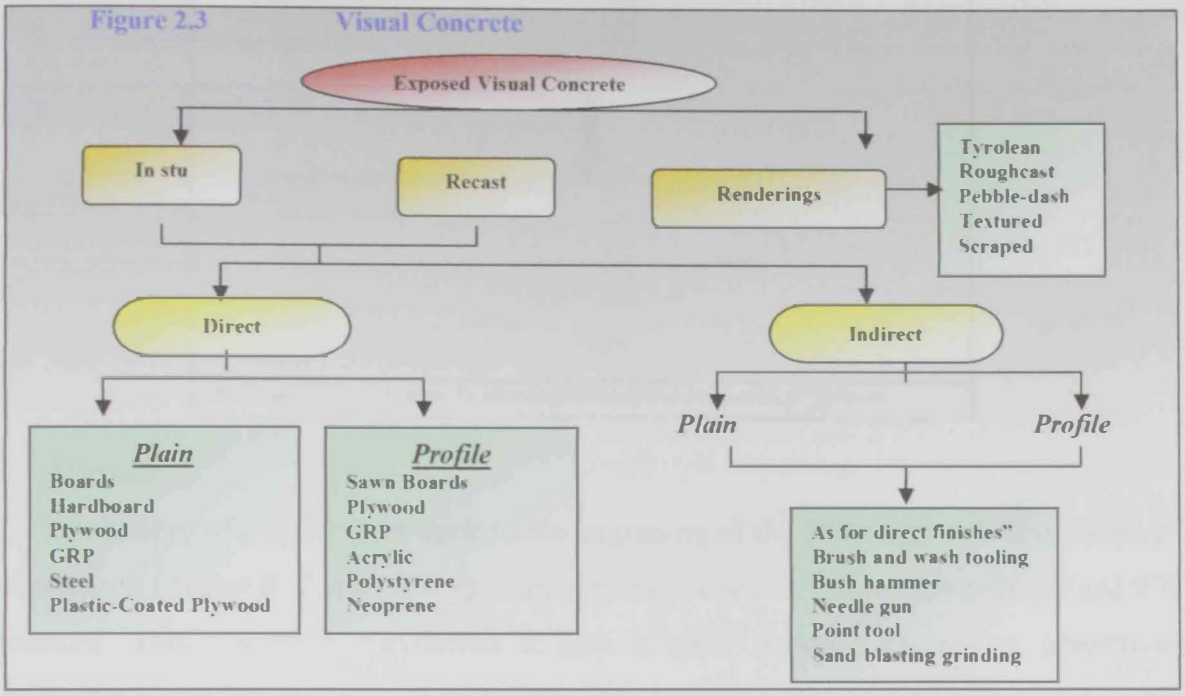
C General Properties:

In general, concrete is required to be hard, strong durable, dense, non-porous, fire resistant and economical. Still for certain structures as in internal partition, strength permeability are not necessary requirements (W.B. McKay, 1991). The production of concrete can be done in two ways: ***in stu*** and precuts manufacturing. In stu states for one of the two methods of concrete mixing but on site and which requires a high standard of quality control during the manufacturing process. But careful consideration must be given to correct specification and detailing of the material to provide a quality finish which weather appropriately.

Where as the appearance of visual concrete depends on three basic factors: composition of concrete. But our main concern in this study is with concrete visual appearance that differs in

it is methods of manufacturing according to required final finishing appearance and textures that best suit of design purpose. The below flow chart (Figure 2.3) illustrates the types of visual concrete according to formwork and surface treatment.

Figure 2.3 Visual Concrete



2.5 Polymers:

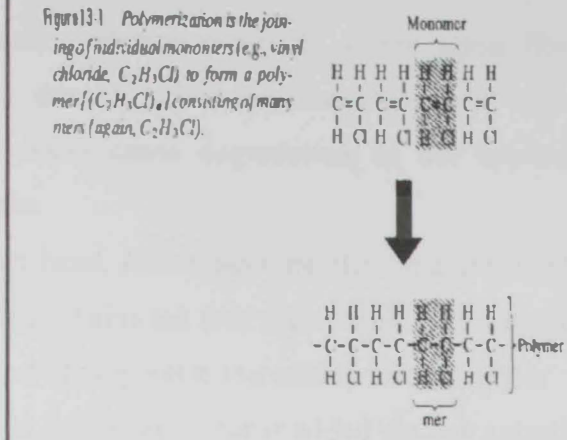
Finally comes the Polymer category of materials and they are well known by their commercial name as "plastics". Their properties and visual appearance depends and varies according to their chemical composition and reactions of which control the form of their bond structures.

Many important polymers are nothing but simply compounds of hydrogen and carbon. Others contain one of the non-metallic elements (Carbon C, Nitrogen N, Oxygen O, Phosphate P and Sulfur S). Those containing oxygen are known as acrylics, when polymer contains nitrogen it is called nylon, presence of fluorine in polymer produces flouro plastics and silicon results in plastic silicones (Yvonne Dean, 1989).

2.5.1 Definition:

Polymeric materials can be defined to be synthetic human made materials, which represent a special branch of organic chemistry. In terms of their chemical composition plastics have a chain like molecular structure composed of a large number of repeated unit is known in the name of "mer" as shown in (figure 2.4). It's important to note that the word "mer" is a "Greek word that means measure. And they are the repeated unit blocks in a polymer material of any kind. The mer in a polymer is a single hydrocarbon molecule such as ethylene -(C 2 H 4)-.

Figure 2.4 Polymerization Action



Data Source: Introduction To Materials Science For Engineers, 5th Edition

2.5.2 History:

The history of plastics goes back to the beginning of the 1900's. It was first done by the polymerization (Arthur R. Lyons, 1997) of an ethylene monomer under high pressure and 200°C temperature. This operation transferred it into a clear material known as polyethylene. Polymerization is a term referring to the process in which the individual monomers can combine and exist in a state of lower energy.

2.5.3 General Properties:

Plastics have good tensile strength to weight ratio. They also have a low modulus of elasticity, which categorizes them to being unsuitable for most load bearing situations. Another important property of these plastic materials is their thermal expansion that is high for most of them. For this reason great attention must be paid to careful detailing for allowed thermal movement. Most plastics are water-resistant and therefore do not exhibit moisture movement. All examples of these polymeric materials are combustible. While some have a high surface spread of flame and produce burning droplets, there are other types of plastics when treated with a fire retardant become quite difficult to ignite and some are even self-extinguishing. One of the most important examples of plastic constructional materials is "paints".

It is important to note that, Plastics share with metals their desirable mechanical property of ductility but are lightweight inexpensive materials that are used alternatively to metal ones in structural design applications. But they have lower strength than metals but are of a higher chemical reactivity than that present in ceramic and glass materials. But despite of their limitations polymers are considered to be high versatile and very useful materials. Polymers or "plastics" are available in a wide variety of commercial forms: fibers, thin films and sheets, foams and in bulk as well. But generally, plastics can be divided into three main families:

thermoplastics, thermo-sets and Elastomers, as shown in the (figure 2.5) (James F. Shackelford, 2000).

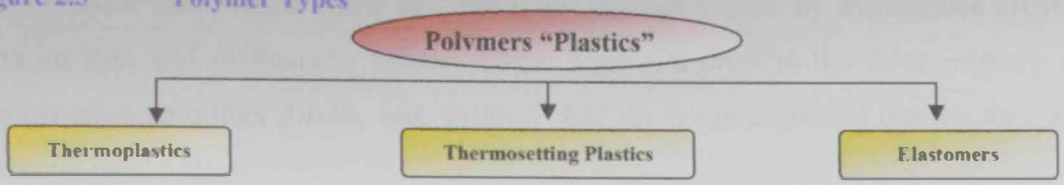
Thermoplastic polymer materials soften upon heating and reset upon cooling, this reversible process doesn't affect the material even with repetition, As long as excessive temperature, that could cause degradation, is not applied. This is all related to the linear molecular structures.

On the other hand, ***Elastomers*** are also long chain polymers in which the natural "helical or zig zag" molecular chains are free and straightened when the material stretches. A good example of this kind of polymeric material is natural rubber. These materials are highly extendible materials, but when sulfur is added the vulcanization process helps the increasing movement restriction by locking the adjacent polymer chains. This is done through the cross linking between these chains which in it is turn is controlled by the amount of sulfur added. This permit is the control over the behavior of rubbery material, which in it is original form is a gummy material, and into tough elastic one instead and a hard brittle material with increasing sulfur content. Vulcanization "is a polymerization process that results in the complete transition from a linear to network structure by cross-linking".

However, ***thermosetting*** plastics are the third type of polymeric "plastic" materials. These are the ones we are most concerned with in our study here for paints and coatings are some of their best and most important examples. For this reason special consideration shall be given to this particular type of materials in the following chapters. But in this chapter we will try to understand the main principles dealing with this kind of polymers and how that affects material properties. It is to be noted that thermoplastics have a three-dimensional structure, formed by the linkage of adjacent macromolecular chains. This three-dimensional structure is responsible for gaining the material; it is solvent resistant and being harder than thermoplastic properties. These materials are not softened by heating and will only "char" or degrade if heated to high temperatures. Production of these materials is usually obtained by partially polymerized powder or by the mixture of two-components (ex: hardener and resin in oil paints). In such cases, resin plays the role of a macromolecular component while the hardener cross-links the liquid resin into the thermo set plastic.

The main difference between thermo sets and thermoplastic polymers is that, not only do thermo sets not loose their rigidity upon cooling but also that they have the characteristic properties related to their network molecular structures formed by ***step growth mechanism***. It is also useful to note those chemical reaction steps can be enhanced by higher temperatures and are irreversible, for polymerization remains even after cooling. The Main disadvantage accompanied by thermoset plastics is that they are not recyclable (James F. Shackelford, 2000).

Figure 2.5 Polymer Types



2.5.4 Paints

With In the Construction industry They Are Usually low-density low-bearing materials that are not subjected to corrosion but they may degrade by the action of direct Sunlight Accompanied with a reduction in mechanical strength and many Of Them Are Flammable unless treated. While there is some natural Based Plastic such as rubber, but the majority of them are petrochemical products (Yvonne Dean, 1989). Paints consist of a blend of components each with their specific function. Commonly these include the binder (or medium), solvent, pigments and additives (Arthur R. Lyons, 1997). All these paint ingredients will be discussed with more detail in chapter 3. But, only a brief introduction will be given here.

The term "paint" and surface coatings" are often used interchangeably. Surface coating is the more general description of any material that may be applied as a thin continuous layer to the surface. Paint was traditionally used to describe pigmented materials as distinct from clear films, which are more properly called lacquers or varnishes. But in the following section of this chapter we will concentrate on the material called paint; but still modern painting may include composite systems in which a total paint system compromises several thin films some but not all of which may be pigmented (R. Lambourne, 1987). As it has been mentioned before, all objects are most vulnerable at their surfaces and need to be protected and/ or decorative; that is what paint does. The paint industry is a wide and very complex one due to it is many applications, types and compositions. But mainly they can be classified into 2main categories: water-base or oil base paints.

A Definition:

Paints are defined as "surface Coatings that are designed to fulfill protective and/or of a decorative function for substrate (J.Boxall and J.A.Von Fraunhofer). Paint is a loosely used word covering a whole variety of materials, with sometimes more descriptive of their composition or function: enamels, lacquers, varnishes, undercoats, Surfacers, primers, sealers, fillers, stoppers and many others (CPA Turner, 1980).

B Paint History:

Paints have been known to man for over 25000 years now. The cave men tended to cover their cave walls with shapes of the animals they hunted, for they believed this would give them increased power over their prey. Some of the chemical analysis of cave paintings

discovered in Spain and France show that the main pigments used by **Paleolithic** artists was based upon an iron and manganese oxides. These pigments provide the three primary colors found in most cave paintings (black, red, yellow). But no white pigments though they are the most commonly used today.

Later It was the ancient Egyptians whom developed the art of paint making during the period 3000-600bc. It was them who developed a wider color range of pigments, which included the following colors and their sources (Table 2.4).

The Greeks and Romans introduced varnishes incorporating oils in the period 600 BC-ad400. Dissolving suitable resins in hot linseed made varnish, hempseed or walnut oil, each of these oils tends to darken with time. By the late 18th century, demands for paints of all types increased so much that it encouraged some people to go into the paint making business. The accelerating rate of scientific discovery had an encouraging impact on the development of paints ever since the 18th century till now. In 1740, Prussian blue was the first artificial pigment to be with a known chemistry was discovered.

After that metal driers for speeding up the drying of vegetable oils started coming into use were introduced in the year 1840. But the basis for formaldehyde resin chemistry was laid down between 1850 and 1890 but wasn't used in paints till the 20th century. Then in 1918 a new white pigment, titanium dioxide was used to white lead (high toxicity) completely. This new pigment was also able to improve the whiteness and hiding ability of paint in addition to it is low toxicity.

Table 2.4 Pigment Colors and Sources

Color	Source	Notes
Blue	Lapis Lazuli 1. Sodium Silicate 2. Sodium Sulphide Mixed Crystal	1. Egyptian blue was first produced 5000 years ago 2. They were obtained by calcining lime, sodium carbonate malachite and silica at a temperature above 830°c
Red and Yellow Ochre's	Iron Oxide	
Yellow Orpiment	Arsenic Tri-Sulphide	
Malachite Green	Basic Copper Carbonate	
Lampblack	Un-complete Gas Combustion	
White Pigment Gypsum	Calcium Sulphate	

Data obtained from: (Arthur R. Lyons, 1997)

C Paint Main Types:

Most coatings used by the painter and decorator can be classified as either: water based paints or oil based paint and in the past decade acrylic paints have been introduced with oil paint physical properties and water base composition.

Water Based Paints are paints that are made up of a pigment mixed with a gum, which acts as a binder; this binder is soluble in water. The traditional gum was gum Arabic, obtained from Arabia, but which has now been replaced by a gum from a species of acacia tree grown in

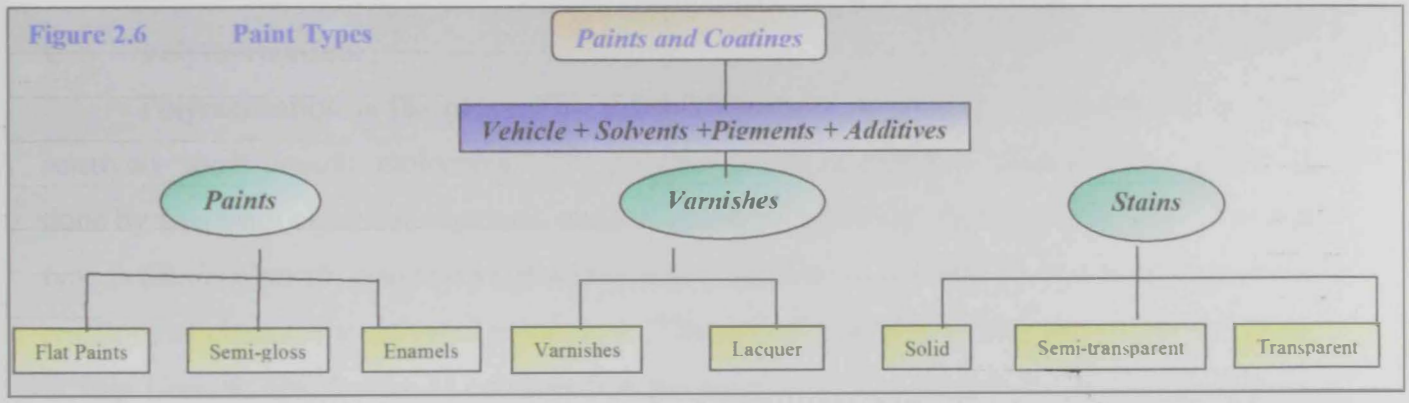
Africa (Ronald Pearsall, 1985). These paints are mainly used for decorative purposes, and they can be divided into two categories: organic or inorganic (J. Bentley, 1998).

Where as ***Oil Based Paints***, are paints that consist of a mixture of white or colored pigment, oil or varnish and inert extender incorporated to reduce cost Other additives like driers, plasticizers, thinners etc are added in small quantities to improve the paint properties drying time, flexibility and durability (J. Bentley, 1998).

As for ***Acrylics Paints, they*** are new comers to the paint industry, a product of modern technology. Their scope is virtually unlimited due to their very adaptable and versatile nature. They are the only new paints to have come on the market for centuries; they were introduced in the year 1962. They can be used as thick like oil paints or transparent washes like watercolor. They can be applied to almost any surface. Their many attribute is that they rapidly dry and ideal used by those who need a top speed work rate (Ronald Pearsall, 1985). Acrylic polymers are a family of entirely synthetic chain growth polymers, whose monomers are mainly esters of the unsaturated acids (CPA Turner, 1980).

Paints and coatings can be divided into are divided into 3 main categories: paints, varnishes and stains (figure 2.6). Each of these categories can also be divided into groups according to their chemical compositions, properties and final appearance and use according to the following figure. But they will each be discussed in detail in chapter 3.

Figure 2.6 Paint Types



C Reaction Mechanisms of Drying Paints:

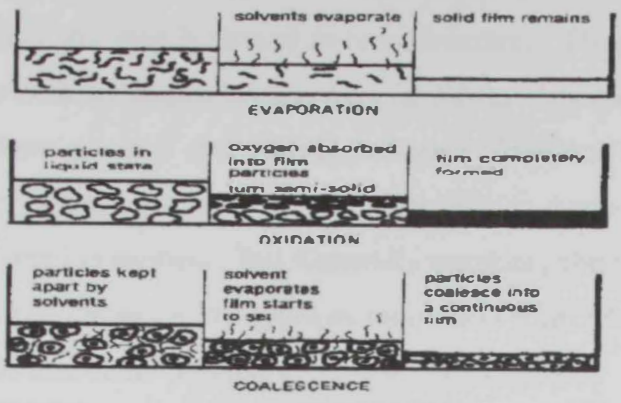
These processes are concerned with conversion of the liquid status of paint into a solid film, which is considered to be quite a complex one. There are 3 mechanisms related to the drying process of different kinds of paints. Most coatings undergo one or a combination of any of the following processes: evaporation, oxidization and polymerization, which were previously, discussed in chapter woof this study.

C.1 Evaporation:

This occurs soon after the paint-coating layer is applied on the substrate surface due to the changing of the thinner into the atmosphere (figure 2.7). This process is known as the setting

up, so that it can no longer be brushed or rolled and it is fluidity property has been lost (A.Fulcher and B.Rhodes, 1991).

Figure 2.7 . Drying Processes



Data obtained from Flucher A. 1991, third edition

C.2 Oxidization:

When drying oils are included in the film former they need to combine with oxygen to complete their chemical change from liquid to solid. Once this has been done and completed the original film former has altered it is structure and the process cannot be reversed meaning it is un-convertible (A.Fulcher and B.Rhodes, 1991).

C.3 Polymerization:

Polymerization is the process by which long-chain or network molecules are made of relatively small organic molecules. The polymerization of polymer "plastic materials can be done by two main chemical reactions: chain reaction or individual chemical reactions. The first type is ***Chain Growth***, also known as addition polymerization, is reactions involving rapid chain reactions of chemically activated monomers. The second type of polymer mechanism for paints is ***Step Growth,*** also known as condensation polymerization is a process of individual chemical reactions between pairs of reactive monomers and is considered a much slower process.

In either of the two previous processes, the critical feature that activities polymerization reactions and allows it is occurring is the presence of double bonds in the chain growth or reactive functional groups in step growth. The chain growth reaction is responsible for converting these double bonds into single bonds. The process begins with an initiator, which is normally a hydroxyl free radical. A free radical is a reactive atom or group of atoms containing unpaired electrons. Once the initiation reaction is completed the one unsatisfied bonding electron is free to react with the nearest monomer, extending the molecular chain by one unit. This chain reaction continues in rapid succession limited only by the availability of un-reacted monomers of the material. Eventually, another hydrocial radical can act as a terminator, helping

in getting to a stable molecule with a number (n) of molecules. When dealing with hydroxyl groups as initiators and terminators, hydrogen peroxide is the source of radicals:

- $H2O2 \rightarrow 2OH$

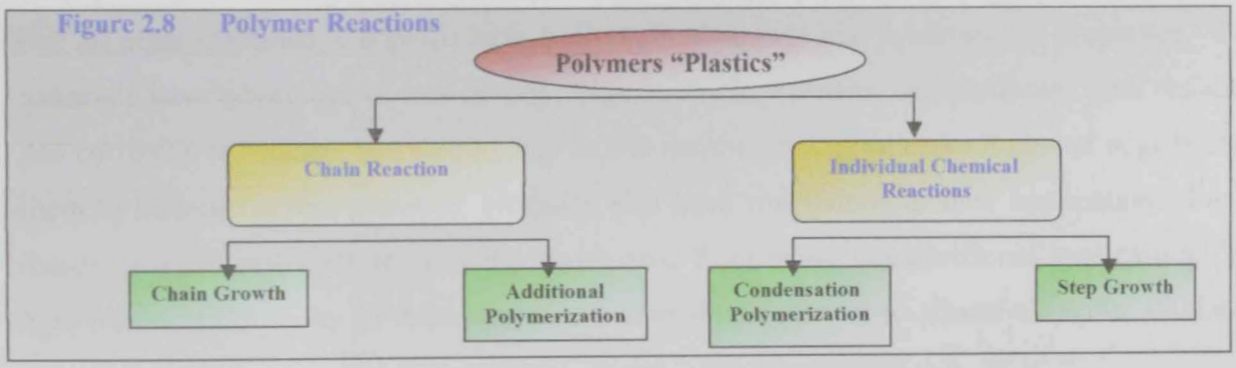
Each hydrogen peroxide molecule provides an initiator-terminator pair for each polymeric molecule. This terminator step is termed as recombination. Though this is one of the easiest ways to demonstrate both ***hydrogen abstraction*** (involves obtaining a hydrogen atom from an impurity hydrocarbon group) and ***disproportionate*** (involves the formation of a monomer like double bond), which ***are*** more common terminator steps than the previously described recombination termination process.

of polymers that are created with respect to the types of monomers from which they are created: copolymers, block copolymers and blend polymers.

Copolymer, are produced from the intimate solution of different types of polymerized monomers. Where as ***Block Copolymers***, are individual polymeric components that appear in the shape or form of "blocks" along a single carbon-bonded chain. The alternating arrangement of different "mer's" can be irregular or regular. The third form, are ***Blend Polymers***, which are another form of alloying in which different types of already formed polymeric molecules are fixed together. From the various linear polymers illustrated in (figure 2.8) we are able to conclude that they are based on a carbon-carbon double bond conversion that transfers them into two carbon-carbon single bonds instead. A similar result of single bonds can be obtained when dealing with a carbon- oxygen double bond, similar to that found in formaldehyde. This can be expressed in the following expression and it is according to this formula many polymer materials are generated (table A4.18):

- $n \quad CH2O \rightarrow (CH2O)_n$.

Figure 2.8 Polymer Reactions



2.6 Summary:

Material science is a very wide and complex field of science. All materials are either constructional or non-constructional according to their type and method of application and required use and most importantly the nature of their internal bonding structure. According to

this field of science materials can be classified into 5main categories: metals, ceramic and glass, composite, polymers and semi-conductor materials.

Metals are materials that have been known since the Iron Age. They were first introduced into are lives for making weapons, but in the end of the last century they have been widely and rapidly used in the construction industry. This is due to their long life spans and ability to be recycled. They are well known to be strong (metallic) versatile construction materials that have the ability to easily undergo extensively permanent deformation without fracture". One of it is important and most useful properties are ductility, allowing it small amounts of yielding to sudden and severe loads. Metals are elements that generally have good electrical and thermal conductivity. While most metallic materials have high strength, high stiffness, and have good ductility others such as iron, cobalt and nickel are magnetic. At extremely low temperatures, some metals and intermetallic compounds become superconductors.

Ceramics and glass represent the second category of materials. Though they have been classified into the same category due to the similarity of their nature, they are quite different. This difference is due to the nature of their internal structure form and bonding which give each it is individual properties that make them different from one another. These materials are usually of a hard brittle nature and the bonding is ionic, covalent or has mixed ionic, covalent characteristics.

These Ceramics are known to be inorganic materials that have non-metallic properties and are usually processed at a high temperature at some time during their manufacture. They are defined to be chemically stable, opaque, materials made up of one of 5 non-metallic elements (Carbon C, Nitrogen N, Oxygen O, Phosphate P And Sulfur S) as was shown in (table 2.1). Their history dates back to ancient Egypt were they were used to decorate various houses. And like all other materials, Ceramics have both their advantage and disadvantage properties. These materials have advantage of low density, high strength, stiffness, and hardness; wear resistance, and corrosion resistance. But due to their brittle nature, tending to make it almost impossible for them to undergo severe pressure, ceramics also have restrictions to their applications. For this reason ceramic materials are usually illuminated from many constructional applications. The high chemical durability of most ceramics makes them resistant to almost all acids, alkalis, and organic solvents.

As for commercial glass, the second group of the ceramic family is based on silica sand as the main ingredient, with additions of other oxides to enhance melting temperatures and properties according to which they are classified into groups, depending on their constituents and the properties, and advantages. Glasses are "super cooled liquids" that gives an increase to it is transparency. Similar to the history of ceramics, glass is also represented by the ancient

Egyptians and Phoenicians as far back as the second millennium. But modern glass is manufactured from silica, sodium oxide, calcium oxide, and magnesium with an addition of small quantities of aluminum, iron and potassium oxides. The physical properties of glass are primarily determined by it is chemical composition. Glasses are one of the 3 main groups: Soda-lime-silica glasses, lead glasses, Boro-silicate glasses. It has advantage of being: Viscous, Corrosion Resistant. Transparent, Hardness and Abrasion Resistant. Still, they have a brittle nature, which makes them weak under tensile stress, although very strong under compression.

On the other hand, Composite materials are any material made from two or more materials, which give a range of properties and behavior not found in individual component materials. They can come from natural or artificial sources.

Wood is a natural material that is a wonderful example of a natural composite construction for both interior and exterior applications and they have great mechanical properties based on their internal fiber reinforced structure.

Where as Concrete, is a good example of an artificial aggregate composite material. They are extremely strong, durable materials with a porous character. Concrete is considered as a universal material of construction. Concrete blocks are structural materials produced from mixing: Portland cement, Water and Aggregates with an addition of certain admixtures to modify the placing and curing process or the physical properties of the block. These materials are one of the oldest construction materials known. The Romans were the first to use concrete in construction of their aqueducts and roadways, over 2000 years ago. In general, concrete is required to be hard, strong durable, dense, non-porous, fire resistant and economical.

Last but not least, Polymers also known as "plastics" are synthetic human made materials that compose of a large number of repeated unit is known in the name of "mer". Plastics have good tensile strength to weight ratio, low modulus of elasticity, high thermal expansion and combustible. Plastics share with metals their desirable mechanical property of ductility but are lightweight inexpensive materials that are used alternatively to metal ones in structural design applications. Despite limitations, polymers are considered to be high versatile and very useful materials and are available in a wide variety of commercial forms: fibers, thin films and sheets, foams and in bulk as well. But plastics can be divided into three main families: thermoplastics, thermo-sets and Elastomers (figure2.3). The main difference between thermo sets and thermoplastic polymers is that, not only do thermo sets Not loose their rigidity upon cooling but also that they have the characteristic properties related to their Network molecular structures formed by step growth mechanism. The Main disadvantage accompanied by thermo set plastics is that they are not recyclable (James F. Shackelford, 2000)

Paints consist of a blend of components each with their specific function. Commonly these include the binder (or medium), solvent, pigments and additives. They are surface Coatings that are designed to fulfill protective and/or of a decorative function for substrate. Paints can be classified as either: water based paints, oil based paint or acrylic paints.

Chapter 3:

Paint Materials

3.1 Introduction

The subject of paints is a very wide and complex One; this is due to the wide range and variety of paint types, colors and textures or physical properties available in the market to suit different requirements, purposes and tastes. Though all paints have the same main components (figure 3.1) on which any paint mixture is based, the fact remains that the main difference between each of them lies on the composition amount of each main component within the paint ingredient. This in it is turn is related either directly or indirectly to requirement, needs and purposes of use that control physical properties of the paint layer applied to any substrate whether it is for interior or exterior purposes.

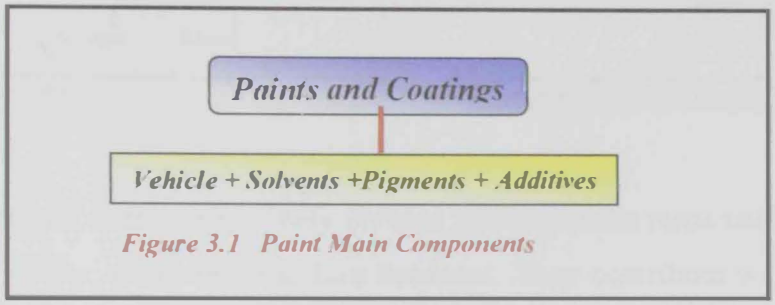


Figure 3.1 Paint Main Components

3.2 Main Paint Components:

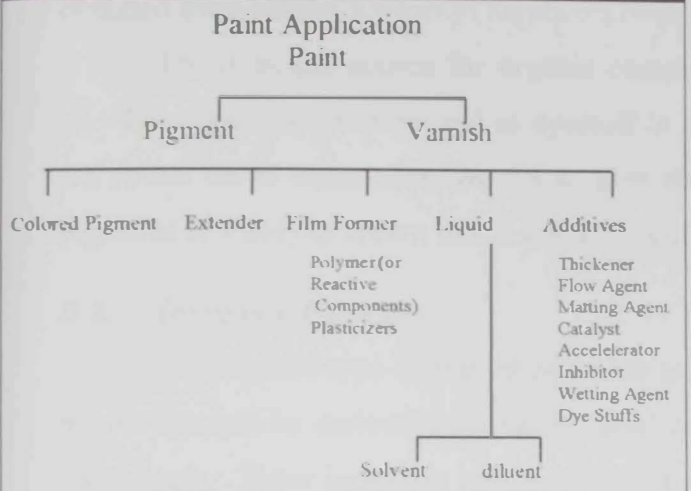
Essentially paint consists of a pigment dispersed in a resinous binder (vehicle), reduced to an acceptable application viscosity with solvent. One or more additives are added to modify one or other of the paints film properties, application or storage characteristics (J.Boxall and J.A.Von Fraunhofer). It is the amount of each of these components that controls paint mixture different properties: color, texture hardness and gloss as in (figure 3.2 and 3.3).

The following sections will discuss each of these ingredients with a bit of detail which will include their origin (natural or synthetic), main role of each ingredient in the paint mixture and their most general properties.

The chapter will also include descriptions of the most common paint types used in the construction field as an architectural finishing material with concentration on those paints used on concrete substrates. Reason behind choosing concrete to be the main substrate for this study is that it is the most commonly used building material used in construction application in the U.A.E therefore, it was found most useful to make it the target on which to apply the study.

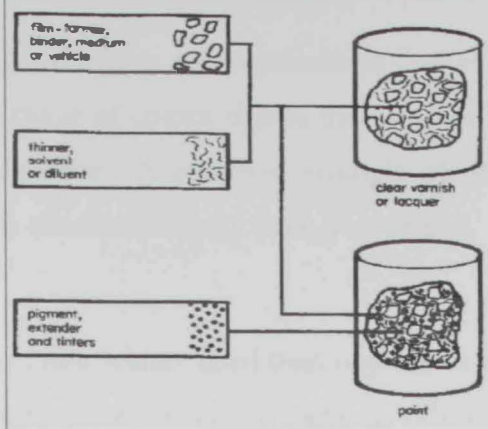
As for the last section of the chapter it will be discussing the necessary substrate preparations required before any paint coat or layer can be applied to any type of surface. This was found essential due to what effect the absence of this step would cause on the final appearance and aim of using these decorative and protective finishing materials.

Figure 3.2 Paint Main Components



Data J.Bentley and G.P.A Turner1998

Figure 3.3 Surface Paint Composition



Data Sources: (A. Fulcher and B. Rhodes, 1991

3.2.1 Pigments:

They are organic or inorganic finely divided solids that are responsible for giving paints their color, hiding power, durability and film hardness. They contribute with 20-60% of paint weight. One of pigments ideal properties is that it should not be soluble in the paint and not react with other paint components. Pigment Vary in Size Shape and Color.

A. Definition:

They are defined as *"any particulate matter that is insoluble in the media into which it is dispersed"*. In other words they are fine solid particles that do not dissolve in the varnish. From this definition the term" pigments" includes: White or colored pigments, Extenders, Anti-Corrosive Pigments (Temple C. Patton, 1973).

B. Pigment Sources:

There are a wide variety of pigment types that are used in the paint and coating industry due to the numerous sources they can be obtained from. Due to these sources pigments can be classified into being: organic (true pigments) inorganic organic (artificial compounds).

B.1. Organic Pigment:

These first types are the natural true type of pigments that come from a living origin, are also known as true pigments. They are defined as "solid mineral substances, which are either dug direct from the earth and are ready for use after suitable treatment and grinding". These pigments are found in Free State in nature but in some cases the natural product is more easily made artificially. Their color is mainly due to the presence of iron. They are completely permanent pigments and form a most useful series of characteristically earthy, relatively subdued

colors, which are inexpensive. Dye colors also fall underneath this first type of pigments and are obtained from nature.

The principal source for organic compounds comes from crude petroleum and coal tar oil. The pigments are produced as dyestuff in a wide range of colors; due to their finesse many are struck on to bases of extenders to give them substance. A common example of organic pigments is Vandyke brown that is not a dyestuff and is obtained directly from peaty earth.

B.2. Inorganic Pigment:

This second type of source pigments are much more widely used than organic 1s and is matter that can be derived from earth, metal or a combinations or heat treatments of chemical compounds. These inorganic pigments, which are also known as artificial compound pigments, are defined as "distinguishable compound pigments that are made by chemist in a laboratory or factory in large quantities". From the definition it is understood why there is a variation of cost between the two types (Norman Colquhoun, 1985). These inorganic pigments can be obtained from one of the following sources and they are:

- **Colored Earths:**

These are sometimes also called" earth or natural pigments". They can be mixed and grounded into fine powders. Examples of these Pigments are: yellow ochre, raw umber.

- **Combinations or Heat Treatments of Chemical Compounds.**

Prussian blue and zinc chromate are common examples for this source of pigments.

- **Metals Chemically Treated**

Chemically treated metals are used to render them into fine powders. Common examples of these pigments are titanium white, white lead and iron oxide. Lead and zinc chromates are the most popular inorganic yellow pigments used in paints. Although, lead chromate is no longer used in consumer paints, zinc chromates still are. But unfortunately, they are known to be moderately toxic by the oral route. Where as chromates, are considered skin sensitizers which cause skin allergies and irritations? Chromates have well been known fro their ability to cause tumors in laboratory animals when administrated by: Intratracheal, Subcutaneous or Intramuscularly Injection.

Another important example of inorganic pigments are Lead tetra-oxide which is a very toxic red colored oxide, two which an over exposure can produce systematic lead poisoning. This pigment is mainly used in large quantities on iron and steel because of it is high corrosion resistance properties.

C Pigment Types:

There are many types of pigments, which are used in paint making. They can be divided into two main groups:

D. Pigment Usages:

According to the type of pigments used, they can play the following roles in a paint mixture, which is based on the required end properties as follows:

- Providing opacity or covering power to the paint (special effects such as flip, sparkle)
- Provides color and can Obliterate previous colors
- Aids the film former (vehicle) in protecting the surface against corrosion
- Improves adhesion of the paint film
- Improves the durability and weathering properties
- Reduces gloss
- Modifies flow and application properties (A. Fulcher and B. Rhodes, 1991).

E. Pigment Color:

Pigments are what give paint their color, depending on their origin and what materials they are mixed and reacted with during the manufacturing of paint. Pigments are classified according to their colors, of which there is a wide range. Selection of pigment colors used in any mixture is related to architectural taste or required finishing and physical properties and paint use required and needed.

But there are two most commonly used color pigments in the paint business and they are: white pigments and black pigments. For more details about pigment color variety it is suggested referring to (table. Appendix ii), that demonstrates pigment colors; it also includes information about pigment origin, chemical reactivity, specific gravity principal properties and principal usage.

E.1. White Pigments:

White paint pigments constitute with 90% of total pigments used in paint production. In the past these pigments were mainly lead compounds but they are no longer used because of their high toxicity. Some have that white pigments that were used are: lead white pigments, white talc pigments, and zinc oxide white pigments.

- **Lead White Pigments**

Tests have proved that lead pigments within paint formulations cause lead blood poisoning in children whom ate paint chips or even gnawed on objects coated with paints of a lead content. This is the reason why lead pigmented paints are no longer used in home

construction paints. These toxic pigments have been replaced with titanium dioxide, which has been tested to have very low oral, dermal, and inhalation toxicity.

Still it is important to know that white lead pigments are widely used in marine applications due to their high ability to resist steel corrosion in such areas. There are also other white pigments of low toxicity such as: Calcium Carbonate, Barium Sulfate and Aluminum Silicate.

Though the silica and silicates compromise with a group of mineral dusts they have been proven not to cause any significant oral or dermal toxicity. But, inhalation of crystalline silica can produce **Silicosis,** which is a disabling lung condition disease characterized by fibrous pulmonary tissue that can eventually be fatal. Where as amorphous silica is considered to be much less fiber-genic to the lungs than crystalline type. In general, safe exposure limit is for these dusts are based upon their quartz content, the greater the amount of quartz the lower the exposure and the higher the safety.

- **White Talc Pigments**

These white pigments are divided into to main groups: fibrous and non-fibrous. The fibrous form can produce a response in the lung similar to that caused by asbestos materials. How ever, non-fibrous talc is much lower in pulmonary toxicity than the fibrous form. For this reason the non-fibrous talc forms are being used to replace talc's, which contain mineral fiber. For health reasons, when repeatedly exposed to high concentrations of white mica pigments (below 20 mppcf[1]) of air is considered sufficient to prevent **Pneumoconiosis** development[2].

- **Zinc Oxide White Pigments**

The two most common metallic dusts used in the paint industry are aluminum powder and zinc dust. Which are both low in toxicity when exposed to, by normal routes: ingestion, inhalation and skin contact? Though zinc oxide white pigments are low in toxicity, the inhalation of freshly formed zinc oxide fumes, as those produced by heating zinc metal to high temperatures can cause **metal fume fever,** which is transient set of symptoms characterized by chills, fever, muscular pain and Headache

E.2. Black Pigments

Black pigments come second after white 1s in their constitution within the paint manufacturing. There are two many types mostly used of black pigments

- **Carbon Black Pigments:**

Carbon black pigments are the most commonly black pigments used. They are produced from the incomplete consumption of gas petroleum. Toxicity is negligible

[1] mppcf = million particles per cubic feet
[2] Pneumoconiosis Development = تغير الرئة

when taken by oral route, but inhalation of extremely high levels of these black carbon pigments has resulted in producing pulmonary damage in experimental animal studies.

Carbon black pigments with known amount of poly-nuclear aromatics hydrocarbons (e.g.: 3,4 Benz (α) Pyrene) have produced tumors in animals. While those with non-detectable poly-nuclear aromatics, have not resulted in excess tumors in laboratory animals when tested by various routes of administration (Oral, Dermal, and Inhalation)

- **Lampblack pigments:**

Is the second major black pigment and is produced from the incomplete Combustion of oil.

F. Pigment use type:

According to importance of use of pigments in paint mixtures they can be divided into two main categories or groups: primary pigments and Supplementary Pigments (Extenders, Fillers

F.1 Primary Pigments:

Is what provides paints with: color, opacification and anti-corrosive properties. Pigments can either be organic or inorganic according to the source they can come from. Table 3.1 displays some of the typical primary pigments and what color they demonstrate if used in any paint mixture.

Table 3.1 Some Typical Primary Pigments

Color	Inorganic	Organic
Black	Carbon Black Copper Carbonate Manganese Dioxide	Aniline Black
Yellow	Lead Chromate Zinc Chromate Barium Chromate Cadmium Sulfide Iron Oxides	Nickel Azo Yellow
Blue/Violet	Ultramarine Prussian Blue Cobalt Blue	Phthalocyanin Blue Indanthrene Blue Carbazol Violet
Green	Chromium Oxide	Phthalocyanin
Red	Red Iron Oxide Cadmium Solenoid Red Lead Chrome Red	Toluidine Red Quinacridones
White	Titanium Dioxide Zinc Oxide Antimony Oxide Lead Carbonate (Basic)	-

Flucher.A. 1991

F.2 Supplementary Pigments (Extenders, Fillers):

Which provide help to lower the cost of paints as well as providing them with other properties other than those provided by the primary pigments.

Table 3.2 Some Typical Supplementary Pigments (Inorganic)	
Chemical nature	Type
Barium sulphate	Barites Blanc Fixe
Calcium carbonate	Chalk Calcite Precipitated chalk
Calcium sulphate	Gypsum Anhydrite Precipitated calcium sulphate
Silicate	Silica Diatomaceous silica Clay Talc Mica
Flucher. A. 1991	

G. Extender Pigments:

This section will be devoted to the description of extender pigments, which are also solid constituents of paint and are used in many types of surface coatings extenders are also known to be transparent in oil, which gives them the opportunity of not having an influence on the color of oil paints. They are sometimes referred to as "mineral whites" usually found in a white color. In other words we can say that pigments fall into two principal groups namely pigments or extenders. If they don't provide color they are called" extender particles".

Table 3.3 Extenders Types, Origin, Properties and Usage					
Extenders	*Origin*			*Specific Gravity*	*Principal Use*
	Earth	*Organic*	*Inorganic*		
Barites	√			4.5	Pigment in water paints Extenders mainly in undercoats
Blanc Fixe			√	4	Improves flow of eggshell finishes
Terra Alba	√			2.3	Water paints Primers Sealers Fillers
With rite	√			4.3	Improves durability and color permanence
Paris White Or Whiting	√			2.7	Fillers pigment in cheap water paints Gives body to undercoats
Silica	√			1.9	Good flatting agent Improves inter-coat adhesion Road line paints
China Clay	√			2.6	Good opacity in water paints Suspending and flattening agent in oil paints
Fuller's Earth	√			2.5	Anti-settling agent
Talc	√			2.8	Flattening anti-settling and fire resisting properties
Asbestine	√			2.9	Suspending and flattening agent Used in wood fillers
Mica	√			2.8	Resistant to shrinking, chalking and cracking Good moisture barrier
Wallostonite	√			2.9	Extender for decorative paints
Flucher. A. 1991, third Edition, Page 71					

Extenders are obtained from natural materials, which are mined and ground into a fine powder. They are much cheaper than primary pigments and can improve the function of paint due to their following properties:

1. Allows the ease of application for certain paints
2. They give greater adhesive properties to undercoats
3. They provide a roughness in the film of undercoats to improve adhesion of finishing paints
4. Prevents certain dense pigments settling out of the paint.
5. They help in giving bulk to certain paints which do not contain white
6. They provide added hardness to paint films
7. Improve the flowing property of certain paints (A. Fulcher and B. Rhodes, 1991)

Table (3.3) illustrates some of the most commonly known and used extenders and includes information about their types, origin, properties and principal usages. Extender types differ according to their uses, but from the table we can see that extenders are mainly used in primers and undercoats

H. Anti-Corrosive Pigments:

Are pigments that are used to protect metallic substrates against corrosion. Mainly, they can be divided into two broad classes of metals and salts (J.Boxall and J.A.Von Fraunhofer). The most common and effective anticorrosive pigments have been based on lead or chromate. But both of these metal pigments are causing concern on the grounds of toxicity. Due to this other kinds of pigments are being used as replacements to these to metallic anti corrosive pigments or a total replacement of traditional primers by other technologies such as electro-galvanizing (R. Woodbridge, 1991) Powdered aluminum and stainless steel are also being used. It is important to note that corrosion inhibitory salts contain water bleachable anions, which can passivate the metal or affect the corrosion process. With these pigments the mechanism of protection differs from that of metal. For more details on the various common anti-corrosive pigments used in the paint industry and brief notes of their usages and properties see table (A4.4) in appendix II.

I. Choice of Pigments:

In order to be able to control and properly select and choose a certain pigment for any paint mixture it is widely advised that we know about some of their physical properties. These properties help in the output-required result tended to be reached.

I.1. Tinting Strength:

Almost all paints consist mainly of white pigment, which is tinted to the appropriate pastel or mid-shade with colored pigments. If a lot of colored pigment is required to reach the required shade, it is said to have a poor tinted strength. The tinting strength of pigments is

independent of it is hiding power, since the comparison of the shades is done at film thickness that completely hides the substrate. Therefore, transparent pigments are considered to have high tinting strengths.

I.2. Light Fastness:

Is the ability of a color not only to be good but also last as long as the paint film? Many pigments fade or darken due to being subjected to light rays, causing the chemical change in their structure. This change means a change in the ability to absorb light in a visible region of the spectrum. Where as in the case where pigments remain with the ability of absorbing UVR without breaking this will help in protecting the binder; the energy is released in the form of heat.

I.3. Bleeding Characteristics:

Not all pigments are completely soluble in all solvents. Meaning that some colors tend to change color effects when applied on to another color layer. A good example of this is when a red paint is applied over a white background and part of it gets mixed into the white causing a pink color to show. This is what is known as bleeding effect (J.Bentley and G.P.A Turner1998)

I.4. Hiding Power:

This is usually expressed as the number of square meters covered by 1liter of paint to produce complete hiding of the substrate underneath the paint layer. Hiding power depends on the wavelengths and total amounts of light that's a pigment will absorb on it is refractive index and also on particle size and shape.

I.5. Refractive Index:

This property is related to the suffering of light rays from refraction, diffraction and reflection by transparent particles that have a refractive index differing from that of the layer in which they are positi1d. It is well known that white pigments which are found in a powdery form are transparent in large lumps; because they have high refractive indices, greater than that of the film-former which provides the film with it is white color. On the other hand, Extender pigments are transparent in bulk and are as white as powders, but they do not color paint because their refractive indices scarcely differ from those of the film formers (vehicle).

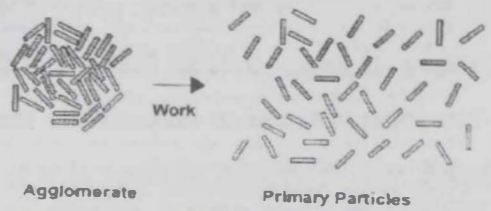
I.6. Particle Size:

Usually, pigment particle sizes range between (44-. 01) microns in diameter. But generally the size used is less than 3 microns in diameter; this is due to the fact that there is an ideal particle diameter for maximum scattering of light at interfaces and this is approximately equal to wavelength of the light in the particle. The optimum diameter ranges between .2-.4μm,

any particles below this size loose it is scattering power. Where as, sized particles above this range causes a decrease in the number of interface in a given weight of pigments. No sample of pigment contains particles all of the same size; rather there is a mixture of sizes with an average diameter.

Connected to the particle sizes of pigment used in any paint mixture is surface area and oil absorption. It is recommended to consider that for any fixed weight of pigments, the smaller the particles the larger the area of pigment surface. On the other hand, the surface area is indicated by the oil absorption, which is the minimum weight in grams of a specified raw linseed oil that is required to turn 100g of pigment into paste. Oil is added slowly to the pigments with thorough mixing and shearing between the walls of the vessel and a rod. During what is called the "wetting" process oil is to replace the air molecules on the particle surfaces. It is necessary to know that during this process the pigments remain as a crumbly mass. When these pigments are in dried powder they are called agglomerates between the individual particles. This individual particles need to broken down through a dispersion process and the prime pigment particles are separated.

Figure 3.4 The Pigment Dispersion Process



Data source: J.Bentley and G.P.A Turner1998

Oil is added slowly to the pigments with thorough mixing and shearing between the walls of the vessel and a rod. During what is called the "wetting" process oil is to replace the air molecules on the particle surfaces. It is necessary to know that during this process the pigments remain as a crumbly mass. When these pigments are in dried powder they are called agglomerates (figure 4.4), between the individual particles. These need to broken down through a dispersion process and the prime pigment particles separated. After the wetting operation has been completely completed the addition of oil will fill the spaces between the particles, which create a paste mixture due to the free moving force they gain as a result of oil lubrication (J.Bentley and G.P.A Turner1998).

It is also important to know that Pigments below a certain range size may have cause serious health hazards to those who handle it. For example, Particle sizes of 10-0.5 microns are in the size of desirable dust, which makes them in a size very easy to inhale. Inhalation of such sized of dry pigments can be the cause of significant inhalation hazard to persons handling these materials. But, the fact is, once dry pigments are incorporated into the paint their potential health

hazards tend to greatly decrease. Method of application also affects the health hazard issue as well. For spray produces greater danger than the brush or roller paint application method.

I.7. Particle Shape:

Pigment particles can be found in several geometrical shapes but the most common shape is the spherical one as that for Titanium Dioxide. They can also be found in other shapes: needle-like pigments (e.g. **Zinc Oxide**) or even sheet-like pigments (e.g. Mica, Talc).

Particle shaping greatly affects the packing style of the pigments and therefore the hiding power. Rod-shaped particles reinforce paint films as iron bars do for concrete or they may reduce surface gloss of surface if they poke through it.

Such rough surfaces may help the next coating layer to stick more easily, that's why such shaped pigments are very useful in undercoat paint. Plate-like pigments overlap one another like tiles on a roof making it more difficult for water to penetrate through surfaces good examples of this type of are Aluminum and mica pigments.

I.8. Specific Gravity:

Specific gravity is related to the weight of a substance in grams divided by the net volume in milliliters. The specific value differs from one type of pigment to another. Titanium dioxide has a value of 4.1; while white lead has 6.6. Specific gravity is quite important because they are sold in kilogram to paint makers and in liter to customers. An expensive pigment/kg may be considered economical if it is specific gravity is low. Extender pigments are normally cheaper in price due to their low specific gravity giving it the power to be used in increasing pigment volume when we need to have a good enough hiding power of the colored pigments at low concentration.

I.9. Chemical Reactivity:

This property can make some pigments unsuitable for certain purposes; such as when dealing with zinc oxide that shouldn't be used as a white pigment with resins containing a high proportion of acid groups because that only will cause the formation of soap. If this tends to happen the paint is said to become 'livery' and unusable.

On the other hand in some cases pigments of this sort are added because they are chemically reactive. Good examples of such pigments are the anti-corrosive 1s. Especially effective with chromates of zinc, when paint film is permeated by water these pigments slowly release chromate ions because of there low but measurable solubility this encourages the pigments.

These examples illustrate the advantages of knowing the pigment chemistry that has proven to be extremely necessary with the newer (probably organic) pigments of which the

manufacturer might not disclose the exact chemical nature. Even in case of more traditional pigments the pigment manufacturer to alter the pigment crystal shape or to provide a coating on the pigment surface that will make the pigment easier to disperse may add other ingredients. Unless exact information is available the paint formulation is in the hands of the pigment manufacturer and relies on their literature.

I.10. Thermal Stability:

The temperature at which a pigment decomposes or alters it is nature is very important if the pigments are required for a paint to be stoved to a high temperature or if the paint is to be heat resistant (J.Bentley and G.P.A Turner1998).

3.2.2 Solvents (Thinner= Dilutent):

Solvents which play a major role in deciding paint type are used for the purpose of making the coating liquid enough to be easily and evenly applicable. During the drying of the paint it evaporates completely once the coating has been applied. The most common thinners used are water, White Spirit, Xylol, Methylated Spirit and mixtures of special solvents.
Some of these liquid thinners are supplied separately from the paint containers in order to be added during the paint job according to adjust the consistency of the paint to the required needs. This is the case usually in oil paints.

A. Definition:

"*They are volatile liquids added to paints to dissolve the binder (resin component) and or to modify the paint viscosity.*" (J. Boxall and J.A.Von Fraunhofer). The main purpose of the solvent is to dissolve the resins, while the diluent and thinners reduce the viscosity of the paint to an acceptable level for application. Choice of the optimum solvent or solvent blend will also influence the flow of the coating and the rate of the drying especially in the early stages (R. Woodbridge, 1991)

They are known to be colorless and are selected according to the types of paint they are employed. Though they are incorporated in the liquid part of the paint they tend to evaporate from the film during the drying process.

B. Chemical Types:

There are 7 main classes of solvents that are used in paints to carry the pigments and binder and they are as follows:

B.1. Water:

Is the main ingredient of the continuous phase of most emulsion paints? It is important that water can be used in many styles either all or blended with alcohols or ether alcohols to

dissolve water-soluble resins. As a fact water now days is considered to be the major" solvent": used in decorative paints in addition to that it holds a strong position in paints used in the car manufacturing and in can lacquers.

The virtues of using water are it is availability, cheapness, and lack of smell, non-toxicity and non-flammability (A. Fulcher and B. Rhodes, 1991). But still on the other hand it does have it is disadvantages when used. This is due to it being not an ideal paint liquid because of it is limited miscibility with other liquids. Another reason is because film formers designed to be dissolved or dispersed in it usually remain permanently sensitive to it. It is availability in nature makes it one of paint films worst enemies, since it is always around and present to cause swelling of the film, hydrolysis and substrate corrosion. Other major problems with water borne paints concern the rheolgy of the paint and it is drying. Where drying is concerned, water has 5 times the latent heat evaporation of organic solvents and it is rate of evaporation is also affected by the relative humidity available in the surroundings at the time of drying.

Still these difficulties are being understood and overcome, and the use of water is set to continue to increase while the use of organic solvents will continue to decrease (J.Bentley and G.P.A Turner1998).

B.2. Hydrocarbons:

In this following section of hydrocarbon type solvent materials used in paint manufactures can mainly be divided into 2main groups of hydrocarbon solvents and they are divided as follows:

- **Solvents, which are obtained during the distillation of crude oil: petrol, white spirit and paraffin.**

White Spirit is one of their most commonly used types. They are greatly known as aphetic blends of paraffin's of available composition, but with a 15-18% aromatic content. Slow evaporating and dissolving most natural resins, oleo-resinous varnishes and medium- and long oil alkyd resins. White spirit is commonly used as the main solvent for brush applied decorative and protective based paints based on these binders. It is also used as a cleaning and degreasing solvent

- **Aromatic hydrocarbon solvents, obtained from the distillation of coal tar: solvent naphtha, benzene, toluene and Xylol. These are used in chlorinated rubber and nitro-cellulose paints** (A. Fulcher and B. Rhodes, 1991).

- **Toluene ($C_6H_5CH_3$):**

Is an aromatic hydrocarbon solvent used in solvent blends for air-drying vinyl and chlorinated rubber coatings as well as a diluent in nitrocellulose paints

- **Xylene ($C_6H_4(CH_3)_2$:**

Is an aromatic hydrocarbon solvent used as a solvent for short-alkyd, vinyl, chlorinated rubber and polyurethane resins. The good solvating power and moderate evaporation rate of this solvent permit it to be used for sag-resistant spray applied coatings, even within relatively thick films, as well as for stoving-cured coatings.

B.3. Alcohols:

This solvent used to be produced by distilling fermented potatoes and starch. But now days they are being manufactured through chemical processes.

- **Butyl Alcohol (C_4H_9OH):**

This alcoholic solvent is also known by the name ***Butanol***. It has the property of being a slow evaporating solvent for a wide variety of oils and resins, particularly amino and acrylic resins and also in solvent combinations for nitrocellulose resins.

- **Ethyl Alcohol (C_2H_5OH):**

This alcoholic solvent is also known by the name ***Ethanol***. It is usually used as an admixed with methyl alcohol, dyes, and toxins in the form of industrial alcohol (Methylated Spirit is). It is a fast evaporating solvent that is used for Poly Vinyl Butyral as well as with other solvents for nitrocellulose.

- **Ethylene Glycol Monoethyl Ether ($C_2H_5.O.CH_2CH_2OH$):**

This alcoholic solvent is also known by the name ***2-Ethoxyethanol***. It is also a slow evaporating solvent for many resins, which is often added to brush applied formulations that cannot incorporate aliphatic hydrocarbons such as white spirit. The high boiling ethers are widely used as coalescing aid solvents in emulsion paints; ethylene glycol monobutyl ether acetate is a typical example (J.Boxall and J.A.Von Fraunhofer).

B.4. Ketones:

Ketones are manufactured in a similar way to that in which alcoholic solvents are made and they can be divided into the following.

- **Acetl ($CH_3.CO.CH_3$):**

This ketone solvent is also known by the name ***Dimethyl Ketone***. It is a fast evaporating solvent used for vinyl copolymers and nitrocellulose. It is also blended, at low addition levels, with many other solvents. When it is high solvating power and evaporation rate modify the properties of the liquid paint and the film.

- **Methyl ethyl Ketones ($CH_3.CO.C_2H5_3$):**

This ketone solvent is also known by the name ***(MEK)***. Is a very strong solvent with a fast evaporating rate widely used for vinyl copolymers, epoxy and polyurethane systems. It is often blended with less powerful solvents to modify the film forming properties and application characteristics of coatings.

- **Methyl Isobutyl Ketone ($CH_3.CO.CH_2CH(CH3)_2$:**

This ketone solvent is also known by the name ***Dimethyl Ketone***. It is a fast evaporating solvent used for similar applications as that for MEK solvent but with a considerable lower required evaporating rate. It is also used at low addition levels in solvent blends where it is fast evaporating rate and high solvent power will improve the properties of the liquid paint and film forming characteristics.

B.5. Esters:

They are solvents, which are derivatives of acids and are widely used in nitrocellulose finishes. Common examples of this class of solvent are ((A. Fulcher and B. Rhodes, 1991) :

- **Butyl Acetate ($CH_3.COO\ C_4H_9$):**

This ester solvent is with a moderate fast evaporation rate and is also of a general applicability. In the past it used to be the major solvent for nitrocellulose coatings. But now, it is used for a wide variety of synthetic resins but is less powerful then the ketone solvents

- **Ethyl Acetate ($CH_3.COO\ C_2H_5$):**

This ester solvent is of a fast evaporation rate and with a pleasant odor, which is often preferred to that of the stronger, smelling Ketones. The major application for this type of ester solvent is in nitrocellulose coatings but now it has a wider application. It is important to know that they have a lower solvating power than that of ketone solvents (J.Boxall and J.A.Von Fraunhofer)

B.6. Ethers:

They are solvents, which are prepared by chemical actions on certain other solvents. They are known to be widely used in cellulose resins and many other synthetic finishes. Glycol ether and methyl glycol are ether type solvents:

B.7. Chlorinated Hydrocarbons:

They are solvents, which are produced by a reaction of chlorine on various materials such as methane. Their main disadvantages are of them being toxic but on the other hand they have the advantage of having the property of being non-flammable. These solvents are divided into two main types:

- **Methyln Chloride:**

This chlorinated hydrocarbon solvent is a very strong solvent used as the main constituent in paint removers.

- **Trichloroethylene:**

This chlorinated hydrocarbon solvent is a very strong solvent used as a degreasing agent.

C. Solvent Properties:

Generally speaking all solvents have some general properties that are very useful in the painting industry:

- Act only on the medium of the paint
- Remain long enough in the wet paint to allow ease of application
- Are free from residue which may affect the film
- They are colorless and do not cause discoloration
- They are not very strong enough to soften underlying coats ((A. Fulcher and B. Rhodes, 1991).

But still there are other important properties of a liquid for any paint that must be considered in order to be able to make the right selection for any paint type. To be able to do that we should know these properties and how they can affect our selections:

C.1. Solvency:

This means whether or not tit is a solvent or non-solvent for a given film former; this depends on the film former and is not an independent property of the liquid

C.2. Viscosity or Consistency:

Which is the outward evidence of the internal resistance to flow and can be measured in unit is called "poises: or in SI unit is or "Pascal/sec." It can be measured by any method involving either the flow of the liquid or the movement of some objects in the liquid.

C.3. Boiling Point or Evaporation Rate:

It is known that the flow of paint on any vertical surface is controlled by the solvent operation. Therefore in order to get the right solvent balance we must be aware of the right solvent balance. This information can be obtained from solvent property tables as shown below:

C.4. Flash Point:

Is the lowest temperature at which a substance will give a flammable vapor. With the exception of chlorinated hydrocarbons and water that are non-flammable, but all other solvents have different flash points and which have been mentiId in the previous table. Most countries

have regulations concerning the storage, transportation and use of products containing the more highly flammable solvents

C.5. Chemical Nature:

Since solvents are nothing but chemical substances, that makes them willing to react with other substances. This is of course undesirable for stability in a can of paint and has to be taken in consideration during the process of manufacturing and storing.

C.6. Toxicity and Smell:

It is very important to know that smell of a liquid may be enough to prevent the use of it for some purposes, though it is mainly built on customer opinion mainly. Some liquids like benzene have a poisonous affect and others can be quite harmful if they exceed certain concentrations in the air. Toxicity level information is also obtainable from data tables. Some liquids such as benzene have a cumulative poisonous effect and others can be harmful above certain concentrations.

3.2.3 Vehicle (Resin= Film former=Polymer):

A number of terms are used interchangeably to describe the film-forming component of the paint. "Film former", "vehicle", "binder" all is terms that relate to the event fact that this paint component carries and then binds the different paint components together and to the surface being applied. This of course provides the continuous film-forming portion of the coating. Resin or varnish are old terms relating to this paint component related to the previous use of natural resins in solution or "dissolved" in oils as the film former. This dates back to when the chemistry and composition was still not understandable. But now a day, better knowledge of this widely used finishing material has been achieved along with the wide application of the sophisticated polymers used also in the plastics and adhesives industries. It is best and more accurate to refer to this paint component as the polymeric film-forming component.

Film-forming polymers may or may not be made in the presence of a solvent. However; since polymers are solvent free form generally range from high viscous liquids to hard brittle solids; they are practically always handled in storage and in the paint making process solution (or in dispersion) with significant quantities of solvent or diluent included.

Most polymers used will be found in a true solution, with solvent being the other component. Still, in certain cases due either to polymer preparation or final use requirements, the polymer will be in the form of fine particle dispersion and for the emulsified materials used in electro-deposition and certain other water-base applications (R. Lambourne, 1987).

A. Definition:

Film forms are defined to be "The polymeric or resin binder of paint is the film-forming component of the formulation". They are also defined as "the polymeric materials composed in the binder portion of modern paints that have a function of holding the pain to it itself as well as the substrate (painted object)". Without the presence of this paint component the continuous coating wouldn't be possible.

B. Binder Types:

Paint binders can be divided into two main categories: convertible and non-convertible types.

B.1. Convertible Coatings:

These film formers can be defined to be materials that are used in an un-polymerized or partially polymerized state which after being applied to the substrate undergo a polymerization reaction to form a solid film. There are sub-types to this category:

- **Oils and Oleo Resinous Varnishes:**

The use of oil paints has been well known throughout history. But in recent times they have been widely replaced due to the introduction of sophisticated polymers, with the exception of a limited. In the next section of this chapter Vegetable oils are classified into two classes: drying or non-drying oils on the basis whether or not they react with air at ambient temperatures to form a rubbery, poorly solvent-soluble film.

In varnishes many types of oil are applicable, but the most commonly used in the practice of paint and varnish manufacturing is: linseed oil, dung or dehydrated castor oil. The method of manufacturing differs based on the nature of used components. Typically for all situations oil is heated and a resin component is slowly added. Heating is continued until the solution is affected; meaning that the viscosity is reduced to an appropriate level with a suitable solvent, usually white spirit.

Next we will discuss the various kinds of resins used differ widely in their composition and characteristics, which has a major influence on the end use of the derived varnish product. Based on this resins are divided into: natural or synthetic resins. The following table mentions the most widely used in the paint industry and discusses some of their most important properties and uses.

In contrast to the properties of films derived from drying oils, varnishes generally tend to dry more rapidly, though driers are still required, and they possess superior hardness, gloss and flow Properties. In certain types like those of Short oil length materials and

rosin containing materials the durability is reduced. The ultimate properties of varnish are determined not only on it is composition in respect of ingredients, but also by it is oil length that is the ratio of oil to resin (Table 3.4) (J.Boxall And J.A.Von Fraunhofer).

Table 3.4 Oleo resinous Varnishes: Characteristics and Uses

Oil length	Oil: resin ratio	Characteristics	Use
Short	~ 0.5-1.5: 1.0	Fast drying Hard brittle films	Fillers Interior Varnishes
Medium	1.5-3.0: 1.0	Slower drying Less hard films	Paints and Varnishes
Long	3.0-~ 5.0: 1.0	Slow drying More flexible and durable films	Exterior Paints and Varnishes

Data From: Fulcher and B. Rhodes, 1991

- **Alkyd Resins**

They are synthetic polyesters that are the most widely used paint binders. Basically these resins are polyester resins produced by reactions of vegetable oil triglycerides, a polyol, (example: is glycerol or pantaerythythritol) and a dibasic acid or anhydride. Generally speaking, there are two manufacturing methods used in the preparation of these resins and they are: flow properties.

- **The Alchoholysis or Monoglyceride Process:**

In this process oil-modified oil alkyds are produced. These resulted oil modified resins are chemically and physically stable. A few mixtures of oil and resin are still being used. Melting the resin and stirring the oil prepare them. But it is important to know that the not all the components are mixed together from the start as in the fatty acid process, but rather Polyhydric Alcohol and modifying oil are first reacted together and then the Polycarboxylic Acid is added.

- **Amino Resins:**

Amino or nitrogen resins are the condensation products of certain compounds with two or more amine groups particularly urea and melamine with formaldehyde. They result from polymerization condensation of an aldehyde with an amine yielding an amino resin (R. Lambourne, 1987). These polymers are insoluble in the common solvents but they are rendered soluble by butylation. Butanol is added to the initial reaction mixture and the butylated amino resins are solvent soluble. The resins will form films by the addition of small amounts of strong acids or by heating at 100-150°C.

The lower cost urea formaldehyde (UF) resins are used in general purpose industrial finishes and acid catalyzed room temperature cured wood finishes. The melamine formaldehyde (MF) resins, with their better chemical resistance, color retention at elevated temperatures, better exterior durability and shorter baking schedules assist

formulation of products with high flexibility, impact resistance, good gloss and excellent water resistance, particularly appliance enamels and automotive finishes.

- **The Fatty Acid Process:**

In this process all 3 components (Fatty Acid + Polyhydric Alcohol + Polycarboxylic Acid) are heated together at temperatures in the region of 240°C until the esterification reaction is complete ((A. Fulcher and B. Rhodes, 1991).

Though both previous process yield oil modified alkyds, they are classified on the basis of the amount and type of oil used. According to that Resins are usually categorized according to the oil content, oil length, and it is nature[1]. The following table illustrates data considered with oil length, Characteristics, use and examples for oil-modified alkyds. The division is based on the oils being either: short, medium or long. This in It is turn affects the end product resulting and therefore as has been previously mentiId the applications to which each may be applied.

Table 3.5 Oil Modified Alkyds Characteristics and Use

Oil Length		Characteristics	Uses	Example
Short	<40%	Non oxidative Soluble in aromatic hydrocarbon solvents Hard brittle films	Used As modifying resins in stoving systems for interior use	Dehydrated - Castor Coconut Oil
Medium	40-60%	Oxidative air drying or stoving cured Soluble in aliphatic aromatic hydrocarbon solvent blends More flexible films	Used As modifying resins in stoving systems for both interior and exterior applications Also it is used in quick air drying systems	Linseed Tall Oil
Long	>60%	Oxidative Soluble in aliphatic hydrocarbon solvent blends More flexible films	Exterior air drying systems	Soya Oil

Data from: Paint Formulation Principles and Practice, Page 4

- **Epoxy Resins**

This type of resins is produced by the condensation polymerization between epichlorhydrin and dephenyol-propane (bis-phenol A), usually in the presence of sodium hydroxide and under reflux. The reaction conditions and the proportions of the two constituents determine the properties of the final product, which is a linear polymer of low solubility in the common solvents but soluble I is often blended with highly polar solvents such as Ketones (R. Woodbridge, 1991).

Coal tar is often blended with epoxy resins and epoxy copolymers to upgrade their resistance to water; these coal tar epoxy coal tar epoxy coatings are used in many marine applications (J.Boxall and J.A.Von Fraunhofer). Generally, the outstanding properties of cured epoxy resins are explained due to their structure. The very stable carbon-carbon and ether links in the backbl contribute to chemical resistance, while a factor of toughness is the wide spacing between the reactive epoxide groups and in turn the

hydroxyl groups. The polar hydroxyl groups assist in adhesion by hydrogen bonding. The aromatic ring structure implies the thermal stability and rigidity property. Although these properties are attractive, Aromatic epoxy resins do have the disadvantage of yellowing which is undesirable. For this reason their major application is for undercoats and primer compositions where adhesion and corrosion resistance is are particularly valuable

- **Polyurethane Resins**

They are two-pack finishes based on hydroxyl functional resins and isocyanate adducts find applications for tough high solvent resisting coatings curing atmospheric temperature or under moderate stoving conditions.

The resins of interest to paint technology are derived from di-isocyanates, typically toluene di-isocyanates is reacted with diol, that is a linear polymer formed, reacts with water and polyolisis that yields cross-linked polymers.

Polyurethane binders fall into two broad categories: single pack and 2-pack materials. Based on this single pack systems can be divided into three groups' types, air curing, moisture curing and heat curing stoving. Where as the two-pack systems, are cold curing, meaning they polymerize in the presence of a catalyst. The properties and uses of these different system materials are mentild in appendix 4 (Table A4.6) Properties and Use of Natural Resins and Synthetic Resin Silicone Resins, early mentild in this chapter.

- **Silicone Resins**

Silicone oxygen and silicon carbon bonds are stable, which has a beneficial influence on the behavior of the semi organic silicone resins in a way that makes them have an exceptional resistance to thermal decomposition and oxidization (R. Lambourne, 1987). These resins differ from the majority of other paint polymers due to tat they are of an inorganic backbl, in the shape of alternating atoms of silicon and oxygen. Silicone resins are produced by hydrolysis of di-and trichlorosilanes causing the resultant to go under a spontaneously condensation.

Pure silicon resins are used for applications requiring very high heat resistance properties ((R. Woodbridge, 1991). Therefore they are only used for stoving finishes, when they yield films with excellent resistance to aqueous media and chemicals. Silicone resins can be blended with other resins to yield films of enhanced durability, water repellency and temperature resistant.

B.2. Non-Convertible Coatings:

These film formers are based on polymerized binders dispersed or dissolved in a medium, which evaporates after the coating has been applied to leave a coherent film on the substrate surface. There are sub-types to this category:

- **Cellulosic Polymers**

Cellulose is the main constituent of plant cell walls and is the most widely occurring of all nature polymers. The primary source for industrial cellulose is either wood or cotton fiber. The material it itself is insoluble but many of it is derivatives are soluble and utilized, like in Cellulosic lacquers. Cellulose polymers films are resistant to water and dilute in acids but are decomposed by alkalis and concentrated acids. Until past recent years cellulose nitrate lacquers were of major importance for the fast drying finishes used on motor vehicles.

- **Chlorinated Rubber**

Natural rubber is not used in paint industry but it is derivatives are. Chlorinated rubber use is quite noticeable. It is prepared by chlorination at about 80-100°C, of masticated crepe rubber dissolved in chloroform or carbon tetrachloride; the reaction product containing some 60-65% combined chloride.

The chlorinated rubber paints can be used as paint binders when they form films by solvent evaporation from solutions in aromatic hydrocarbons. For such films high plasticizers levels are required to provide film flexibility. The materials are also blended with many other resins to assure both water and chemical resistance upon the binder. But their main application is for coatings required to provide high resistance to chemicals and/or corrosion (J.Boxall and J.A.Von Fraunhofer).

- **Vinyl Resins**

The vinyl resin term refers to polymers and copolymers of vinyl chloride, though the term does have a more general meaning. Vinyl chloride is a cheap monomer whose polymers have good color, flexibility, and chemical resistance. These resins include homopolymers of vinyl chloride and copolymers of poly vinyl chloride/ vinyl acetate. The latter one is used in the form of particles dispersed in plasticizers, which is vinyl acetate or a mixed solvent/diluent (organsol).

Vinyl resins are used in coatings for strip Venetian blinds and bottle tops where extreme flexibility and extrusion properties are required. They are also used in heavy duty and marine coatings where properties of toughness, elasticity and water-resistant are paramount and have had an application in coil coated strip for building facings.

- **Acrylic Resins**

Acrylic resins are widely used for their excellent properties of clarity, strength, and chemical and weather resistance. The term acrylic represents those polymers containing acrylate and Mythacrylate esters in their structure along with certain other vinyl unsaturated compounds. Vinyl/acrylic polymerization in a particularly versatile, in that it is possibilities are much greater in condensation polymerization of controlling polymer architecture and in the introduction of special features. A good example of this is the modification stages following the initial formation (R. Lambourne, 1987). It is important to note that acrylic resins are found in both thermoplastic and thermosetting systems. These resins are ideal candidates for automotive finishes; domestic appliance finishes and coil coatings for exterior cladding.

Solvents used depend on the composition of the acrylic polymer-alcohol solvent. The optimum solvent balance will also be influenced by the nature of the cross linking resin to be used. Acrylic resins are also available in emulsion form as lattices or non-aqueous dispersions (R. Woodbridge, 1991).

B.3 Miscellaneous Binders:

There are two other binders that are of a great importance in the paint technology although they are not strictly classified as polymers

- ***Inorganic Silicates***

Inorganic silicates are prepared by the fusion of sand and silica with sodium and/or potassium carbonate, the fused mass then being digested by water. Zinc dust with zinc or calcium oxide is added. And when the solution is applied to a substrate a silicic acid is formed by evaporation of water and interaction with atmospheric carbon dioxide. The silicic acid reacts with the zinc or calcium oxide to form complex inorganic silicates, additions such as potassium phosphates and lithium silicate being made to accelerate the curing rate. This system is a 2-pack formulation. Such zinc dust inorganic coatings have exceptional durability, temperature resistance and corrosion resistance but acids and strong bases may attack them. They dry poorly under wet conditions but their aqueous resistance, especially to seawater, is exceptional and these coatings are used as protective primers for marine structures.

As for the organic-inorganic silicates they consist of zinc dust mixed with ethyl orthosilicate, which is combined with the inorganic silicate system. Both single and two-pack Formulations have been developed. The coating properties are superior to those of the inorganic silicates and they have a longer pot life (J.Boxall and J.A.Von Fraunhofer).

The adjacent table states some of the most important properties and use of some organic substances other than oils and resins and is used in some paints and varnishes (A. Fulcher and B. Rhodes, 1991).

Table 3.6 Properties and Use of Miscellaneous Binders (Other Film Forming Substances)

Medium	*Properties*	*Use*
Bitumen Asphalt Bitumen Pitch	Very Dark Color Excellent Water Resistance Acid-Resistant Low Cost Color Bleeds Through Oil/Resin Paints Softens Upon Heating	Damp proof compounds Bituminous paints
Rubber Can be either natural or synthetic and are treated to form a: Chlorinated Rubber Isomerised Rubber Cyclised Rubber Neoprene Hypolon	Excellent Water Resistant Chemical Resistant Very Flexible Quick Drying Good Flow	Chemical Resistant Paints Water Resistant Paints
Cellulose Nitro cellulose Which is treated with nitric acid	Rapid Drying Hard Film Chemical Resistant Almost Impossible To Brush Tends To Be Brittle	Cellulose Paints and Lacquers Cellulose Stoppers And Fillers

Data Obtained From: Fulcher and B. Rhodes, 1991

- ***Bitumen***

Bitumen resins are used in bituminous paints and are manufactured from natural occurring or distilled crude petroleum oil residues. The grade of bitumen in color and properties depends on both the source and distillation conditions. Naturally occurring bitumen's have high softening points and the distilled 1s are air oxidized to raise their softening temperature.

When dissolved in hydrocarbon solvents, bitumen's form surface coatings by solvent evaporation. These coatings have good resistance to aqueous media, to chemicals, to moderate concentrations of non-oxidizing acids and to bases at regular temperatures. The Blending of bitumen resin with media containing drying oil results in paints with compromised properties. Examples of these properties are rapid drying, and good protective characteristics for the substrate (metal) under moderate-to-severe exposure conditions. The tar-epoxy resins are obtained from blending bitumen's with epoxy resins that improves the epoxy binder properties of impermeability to water and chemicals (J.Boxall and J.A.Von Fraunhofer).

C. Resins Sources:

Resins Are amorphous and describe a physical state rather than an exact chemical entity. The function of resins is to provide film hardness, gloss, surface adhesion, and resistance of the film to adverse conditions such as alkali acids and other harsh environments. Resins are derived from either:

C.1. *Natural Sources:*

Natural sourced binders have been used in the paint industry for centuries. An important example is **rosin.** Wood rosin is obtained from tree stumps via a solvent extraction processes. It is very important to acknowledge that toxicity of natural resins is low, but Abietic acid undiluted can be irritating to the eyes, skin and upper respiratory extract. Abietic acid is one of the most popular acids that build up the rosin extract obtained from trees. These acids all contain a phenanthrene backb1 with various side groups.

C.2. *Chemical Synthesis:*

Chemically obtained binders have commercially been available since 1920. These types of binders are produced by two main polymer reactions: additional polymerization or condensation polymerization.

Figure 3.5 Resins Polymeric Reactions

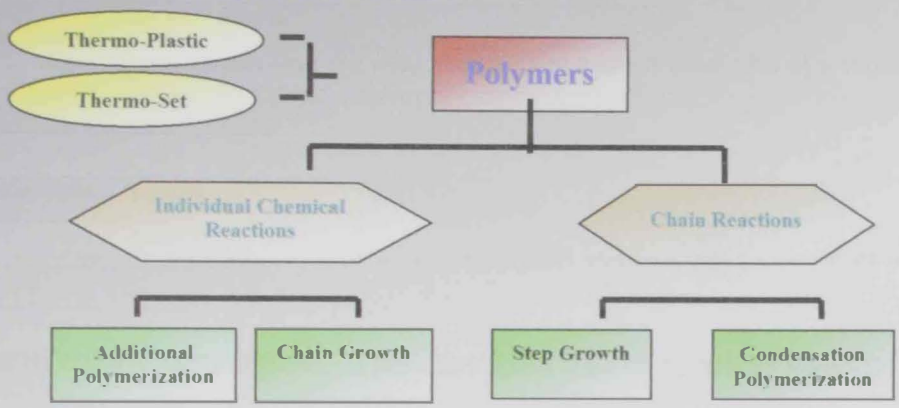
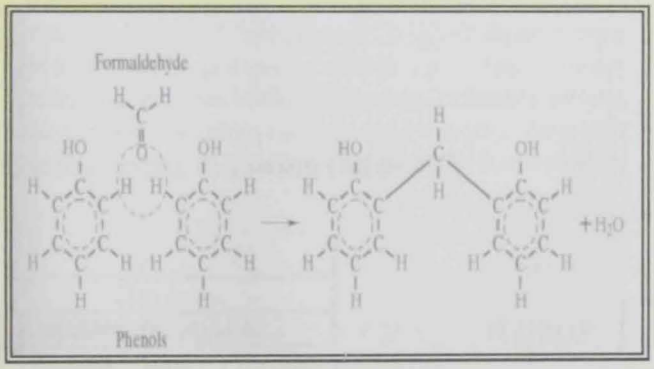


Figure 3.6: Polymerization Chain Growth

Detailed mechanism of polymerization by a chain growth Process (addition polymerization).

Figure 3.7: Polymerization Condensation



Single first step in the formation of phenol-formaldehyde by a step growth process (condensation polymerization). A water molecule is the condensation product

Adapted From Introduction to Materials Science for Engineers, 5th Edition

Additives are one of the ingredients of any paint mixture and though they are present in those chemicals, which perform a special function or introduce a special property to paint. In the applications of use.

The small quantities of substances added to carry out special jobs, such as improvement appearance is that they have a profound influence on the physical and chemical properties of the with so many of them according to required property required for them to achieve.

reactions. It is of a low toxicity by oral route. It is a mild skin and eye irritator as a dust but not

R Additive Types:

Since additives major role are to improve or control one or more of the paint properties it materials to control certain paint. Therefore main role of additives shouldn't be a corrective one "Corrective", many forms an essential part of the have a well-balanced formulation but are main ingredient.

constructive" or negative" corrective additives according to the following (table 3.7).

Table 3.7 Paint Additives

Constructive	Corrective
Dispersion/ Wetting Aids	*Anti-Skinning Agents*
Driers	*Floating and Flooding Additives*
Preservatives/ Biocides (= In Can Preservatives)	*Anti-Gassing*
Insecticide Additives	*Anti- Foam*
Can Corrosion Inhibitors	*Anti Static*
Flash Corrosion Inhibitors	
Ultra-Violet Absorbers	*Anti-Freeze*
Reodorants	
Data Obtained: R. Woodbridge, 1991	

B.1. Plasticizers:

They are defined to be "Organic Additives That Are Used to Increase the Film Flexibility of Paints", Particularly Those Based on Binders That Otherwise Yield Brittle Films. Plasticization can be achieved both internally and externally. Internal Plasticization consists of copolymerization of the brittle resin the major binder component with the aid of a second resin in order to modify the properties. As is the case with vinyl acetate is an example that will plasticize the rigid and brittle vinyl chloride. Though this approach is effective it somewhat of a limited scope and therefore external Plasticization is more widely adopted. As for external Plasticization it is more widely adopted. This process consists of the incorporation of a compatible low molecular weight non-volatile liquid with resin as in the addition of alkyd resins to chlorinated rubber.

Plasticizers are non-toxic and provide maximum film flexibility while having a minimal softening effect on color distortion, especially on external exposure. The amount and type of plasticizers added varies with the resin type and the proposed application for the required coating. These additives affect many properties of the paint film including tensile strength, toughness, extensibility, permeability and adhesion. All these properties are effected to in different degrees that are often in a complex matter according to the polymer and plasticizers types. There are two classes of known plasticizers.

- ***Solvent Or Primary Plasticizers***

  These plasticizers act as solvents for the resin by virtue of the chemical groups which can interact with the polymer and so provide it is compatibility.

- ***Secondary Plasticizers (Non-Solvating)***

  These plasticizers don't have a solvent nature, are non-reactive and can only be compatible over a limited addition range. They only have a mechanical effect and are able in reducing the film strength to a lesser degree. Still, it is possible for secondary plasticizers to migrate or be leached from the film leading loss to the flexibility (J.Boxall and J A.Von Fraunhofer). Most common examples of plasticizers**:** are the Phthalate plasticizers Dibutyl-Phthalate, Diethyl-Phythalate, and Diethyl Hexyl Phthalate and Dibutyl Sebecate.

B.2. Anti Corrosive Pigment Enhancers:

These additives main role are to protect materials especially steel from corrosion. Some of these anti-corrosive pigments are tannic acid derived (Kelate). Albarex is a treated extender used to partially replace true anticorrosive pigments such as zinc phosphate. Alchophor827, described as zinc salt of an organic nitrogen compound, also augments prime anticorrosive

apa solution. For some people it is skin sensitizers. It is inhalation irritant [illegible]

pigments. Ferrophos is recommended to part substitute zinc dust in zinc rich primers (R. Lambourne, 1987).

Alcophor 827	(27)
Kelate	(45/34)
Albarex	(44/15)
Ferrophos	(42)

B.3. Anti Foams:

Latex paints are stabilized with surfactants and colloids that, unfortunately also help stabilizes air introduced during manufacture or during application and this way form stable foam. Non-aqueous paints may also show bubbles. Available anti-foams on the market may be directed to a particular class of the paint offered for general use. Sometimes the additions of 2-anti-foams are made one at an early manufacturing stage and the other just prior to the filling-out. It is usually known that anti-foams provide high surface activity and good mobility, even though they are not actually soluble in the foaming liquid. They function by lowering the surface tension in the bubble neighborhood, causing them to grow into thinner larger bubbles that are less stable which eventually pop. Commonly available anti-foam agents available on the local market by suppliers are:

Foam Master (Nopco) NDW	Mineral Oil Based	(18)
Byk 069	Mineral Oils, Alcohols, Soaps	(8/39)
Byk 031	Mineral Oils Based Stable To Over 100°C	(8/39)
Bevaloid GS32	Silicone Oil Based	(5)
Perenol E2	Non-Silicone for Epoxy System	(27)
Defoamer 1512m	Mineral Oil, Silica, Silicone	(28)
Defoamer L409	Silicone Based For Stoving Alkyds to Lattices	(20)
Defoamer L413	Silicone/Silica Based, For Aqueous Preparations	(20)

B.4. Anti Settling Agents

Paint formulations may yield liquid paint that is to fluid. With a liquid of low viscosity the flow may be excessive for some purposes but an advantage for others. Which is so in stains, sealers, and spraying lacquer but not in high build coatings and brush applied paints? Settlement is most likely to occur especially when the paint is too dense, which is the case in low viscosity paint, and heavy settlement can cause problems in re-dispersing the pigment. Doing adjustment to the paint formulation solves these problems of flow and settlement.

Adding thickening agents' increases level of viscosity without introducing thixotropic increase viscosity (R. Lambourne, 1987). It should be in mind that often anti-settling aids are

used with each other to enhance the effect. The fine particle pyrogenic silica's are useful on their own or with byke anti terra 203. There are so many additives used which have affect on the viscosity at a low shear rate, therefore some also have the influence on anti-sagging, flow control, and color flotation.

In latex paints structure is so commonly formulated into the system that settling is not a problem. For other types of aqueous paint the choice of colloid is important and judicious use of bentonite or pyrogenic silica's can be added to the pigmentation or recourse may be made to Cellulosic or synthetic polymeric thickeners.

B.5. Anti-Skinning Agents

Driers ensure the essential proper balance of surface and through drying characteristics for autoxidative air-drying paints. Unfortunately, they also may cause the formation of a skin on the surface of stored paint. This problem used to be solved by the adding of 1-2% pine oil or dipentine. But, phenolic antioxidants were used for the more stubborn cases.

But now they have easily and widely been replaced by the easily used Oximes. Butyraldoxime ad especially methyl ethyl Ketoxime are now widely used at about .2% on the paint. Being volatile the Oximes are lost from the film in an early stage and do not significantly retard the drying. This volatility can be a disadvantage in the container once opened but with the presence of such agents the problem may now easily be re-lidded without worry. Some antioxidants in certain systems can cause loss of drying potential on storage so both drying and skinning performance must be checked before any selection is made or application in made (R. Lambourne, 1987).

Eatyraldoxime	(53/40)	
Depentine	(37)	(59)
Exkins 1,2 And 3	(53/40)	
Pine Oil	(37)	(59)
Cyclohexan1 Oxide	(53/40)	(4)
Methyl Ethyl Ketoxime	(53/40)	(6/11)
Guaiacol	(7)	(49)

Methyl Ethyl Ketoxime is one of the most common used anti-skinning agents. It has a low oral, dermal and inhalation toxicity but is considered an eye irritator.

B.6. Can Corrosion Inhibitors

It is highly desirable to protect fully lacquered that are used for packaging aqueous paints due to their high ability to under corrosion particularly around minor unprotected areas of tinplate. Sodium benzoate at 1% on total water content is the normal recommendation although

sodium nitrite is sometimes used as an alternative or in conjunction with the sodium benzoate (J.Boxall and J.A.Von Fraunhofer).

B.7. Dispersion/ Wetting Aids

As their name implies these materials are added at the dispersion stage of the paint manufacturing process to assist the wetting/ dispersion of the pigments. They are also known as surfactants, surface-active agents, that very between anionic and non-ionic, cationic or amphoteric. As a general rule anionic types may be preferred for use with inorganic pigments. While non-ionic types are selected for the dispersion and paint stability of organic pigments. In either selection of materials it is important to ensure that only the required amount to assist pigment wetting, dispersion and paint stability is used. Any access of amounts used can have opposite affect on the general paint properties: paint stability, water sensitivity, wet adhesion, foaming tendency, and the creation of other surface defects

There are hardly any general rules that can be given on the use of such additives, other than the usual incorporate of a wetting aid at an early stage so that it has the best opportunity to meet up with the pigment surface and not have to compete or even in some cases replace other liquid components of the composition. Secondly, it is common to make later liquid additions to the mill base carefully and with stirring if the dispersing aids themselves are not to be displaced from the pigment surface. Due to the large selection of these aids it is common for suppliers and additive manufacturers to publish charts showing which dispersant to use for best effect and results. But the most commonly known are:

Byk 104S	Organic With Silicone	for Water Solvent Systems	(8/39)
Disperbyk 163	Cationic Surfactants	for Solvent Systems	(8/39)
Lactimon	Anionic Surfactants	for Solvent Systems	(8/39)
Solsperse Range	Polymeric Surfactants	for Solvent Systems	(31)
Centrol 3FDB	Soya Lecithin	for Solvent Systems	(10/61)
Colorol E	Modified Soya Lecithin	for Emulsion Paints	(15)
Dispex A40	Ammonium Polyacrylate	for Aqueous Film	(3)
Tamol 731	Di Isobutylene Maleac Dispersant	For Emulsion Paints	(50)

B.8. Flash Corrosion Inhibitors

Wherever water base are used it is most likely rust will appear causing stains usually in the form of light brown spots. This so called "flash corrosion' may be over come with the use of inhibitors. Sodium benzoate or sodium nitrate at 1.5-2.0% on water content is often effective but one or more propitiatory products are available.

B.9. Floating and Flooding Additives

Most paints tend to change color slightly during drying to the immigration of some of the pigments to the surface. Flowing is the term usually reserved to color striations or mottled effects. Because of the high viscosity of the setting paint films the areas does not then redevelop it is color (R. Lambourne, 1987). Therefore floating and flooding additives are additives that tend to reduce the lack of color uniformly in the paint film. There are various propitiatory products are available, but results can be very specific and should be checked carefully before arbitrary addition to a batch (R. Woodbridge, 1991).

B.10. Dehydrators/ Anti-Gassing Agents

With some paints it is important to lower the moisture level for the purpose of storage stability reasons. Gassing in the can is usually caused by the presence of moisture in such products as moisture cured polyurethane paints or products containing, Aluminum flake or powder zinc dust. Moisture curing polyurethane paints can only use pigments from which adsorbed moisture has been largely removed if cross-linking and gassing in the can are to be avoided. Good plant house keeping can be of a great help in reducing or even minimizing sources of water contamination, found in solvents, but the addition of water scavering agent such as very fine particle silica or additives based on TI monomeric isocyanate in the pigment dispersion stages are recommended to wipe out any chance of contamination and control the effects of residual moisture during storage.

Another group of products in which water can cause problems on storage are the aluminum paints and zinc dust primers where reaction with the metal with moisture releases hydrogen-causing pressure within the can. Sylosiv Al and ZNl are commonly used in such circumstances, though they are not capable of coping if grossly water contaminated solvents or binders have been used.

Additive TI	(4)
Additive FO	(4)
Sylosiv Al	(25)
Sylosiv ZNl	(25)

B.11. Reodorants

A number of aromatic essential oils have been suggested for masking the odor of paints during application and the immediate post drying stage. In practice it is usually more acceptable to reduce as far as possible the cause of the odor by the elimination of trace monomers or by the use of low odor solvent. Possibly the most widely used additives in alkyd based finishes is a low percentage of pine oil (R. Woodbridge, 1991).

B.12. Driers

Driers are most often metallic salts of lead, calcium, cobalt and magnesium. Toxicity is mainly due to the metal content. Although it is widely argued that the use of driers is a fundamental part of the paint formulation and not an additive and shouldn't be considered as an additive, but still many do believe it is (R. Lambourne, 1987). Driers are materials are used to speed up the oxidization polymerization reactions in air drying, oil containing products. But the drying speed can be rapidly speeded with the presence of certain metal organic compounds. This catalytic activity depends on the ability of the metal cations that is to be readily willing to be oxidized that's why metal driers are applied in practice (J.Boxall and J.A.Von Fraunhofer). Some metal drier examples are mentiId In (Table A4.7 Appendix 4):

B.13. In-Can Preservatives

Aqueous thinned products especially those containing a natural or synthetic colloid or Cellulosic thickening agent are liable to biodegrade unless properly protected with an effective preservative. Such protection should be provided to any liquid raw material supplied or stored in bulk as well as the paint during manufacture and in the can. Formaldehyde is the most commonly used to protect the latex in manufacture, delivery and storage. It also can be a useful means of controlling under carefully supervised conditions, the sterility of manufacturing equipment and pipelines

Being volatile it is less effective as a long term "in can preservatives". A whole range of such preservatives is available; and reference to supplier's literature will indicate optimum levels of use. Both the nature of the ingredients and the PVC of the formulation will influence this optimum level. Higher PVC products tend to require higher levels of preservatives for adequate protection. In formulating exterior coatings it is necessary to consider the addition of film fungicides and algaecides to prevent the growth of mould spores on the film surface. A wide range of additives of this kind is available on the market therefore the selection must be done carefully for the grades appropriate to the type of product being modified

B.14. In-Film Preservatives (Biocides)

If paint films are provided with the right environment they are most likely willing to allow mold growth that will appear in the form of black stains at the junction of walls and ceilings which most likely occur in bathrooms. Similar growth may become visible on building exteriors in the shape of greenish algae. Biocides are additives that are added to the paint in a level below 5%. Those biocides used in can preservatives for emulsion paints are highly soluble, while those used for film protection are needed in quite the opposite. The reason for then needed

not to be soluble is so they may not leach quickly from the film and therefore lose their required effectiveness by condensation as soon as rain falls.

The properties of most film preservatives are those related to biocides that provide best protection against a large range of fungi and algae. Again specialists in these fields are responsible in providing advice and their services on how to make the right choice on which biocide is to be used for and for what purpose that suit is any particular paint composition and the environment it will be positi1d in. examples of these additive materials are: (R. Lambourne, 1987).

Acticide APA (58)

Parmetol (56)

Nopcocide (18)

Mergal (588)

Proxel range (32)

This group of additives is the most toxic, since it is their role to retard mold and bacterial growth in paint. Still they represent only a small part of the paint concentration (usually less than 1%). Some of the most commonly used biocides used in paints and are known to cause skin rashes and irritations and lung problems are:

- ***Phenyl Mercuric Acetate***

Use to be one of the most common biocides used in the paint industry. But it is usage has been dismissed due regulations that state it can only be used within water paints. That was a result of it is high toxic mercury content. It is a strong skin and eye irritator and can cause allergic contact dermatitis is a skin disease that has the form of rash, irritation of the skin or eczema for individuals.

- ***Tributyltin Chloride or Tributyltin Oxide;***

Very little toxicity information available

- ***Tetrachlorophenol:***

Represent the chlorinated phenol type of biocides. They are moderately toxic. The skin doesn't readily absorb it. It is dust is irritating to the eyes, nose and throat.

- **Formaldehyde:**

Formaldehyde is also used as an effective anti-microbial compound in water based paints at low concentrations. It is irritating to the eyes and upper respiratory tract. At certain concentrations (over 6 ppm), which are clearly irritating, they can also produce tissue damage, and has been tested to produce nasal cancel in laboratory rat tests

B.15. Ultra-Violet Absorbers

Many pigments fade and many binders degrade owing to the effect of the incident radiation especially ultra violet. The use of a coat of varnish was shown to slow down the fading of a fugitive paint many years ago but uncomfortably un-Pigmented varnish films themselves degrade quickly. The ultra violet absorber converts the undesirable short wave lengths to heat Energy and the light stabilizer capture the free radicals generated that would cause film degradation. This technology has made it possible to use base coat plus clear coat automotive finishing systems and overcomes the early problems of under film chalking, delaminating and cracking of the top clear coat. Good examples of these additives are:

Tinuvin 900-UV absorbers

Tinuvin 901 – hindered amine

Sanduvor 3206-UV absorber

Sanduvor3046-hindered amine

B.16. Optical Whiteners

These materials absorb ultra violet wavelengths and re-emit the energy in the visible wave band. If they are chosen to emit in the blue violet region they can give a boost to the color of whites overcoming tendency to yellowness. However, although these additives are widely used in the paper and detergent industries they still haven't found a significant output in the surface coating industry because of their short-lived effectiveness and the cost premium incurred. An example of such additives is:

Uvitex OB (13)

B.17. **Insecticide Additives**

Insecticides are not common paint additives, but still they are required from time to time for the use in interior paints to help control flies and cockroaches especially in marine life and on boats particularly. To be effective fairly high levels of insecticides are required and the composition must be such that it can be fed to the surface. Materials used have included Dieldrin, pyrethum and other chlorinated aromatic compounds that are claimed to have insecticidal properties ((R. Woodbridge, 1991).

Zinc Octoate (21) (39)

Copper Naphthenate (16)

Tributyl tin oxide (2)

Priem insecticide (46)

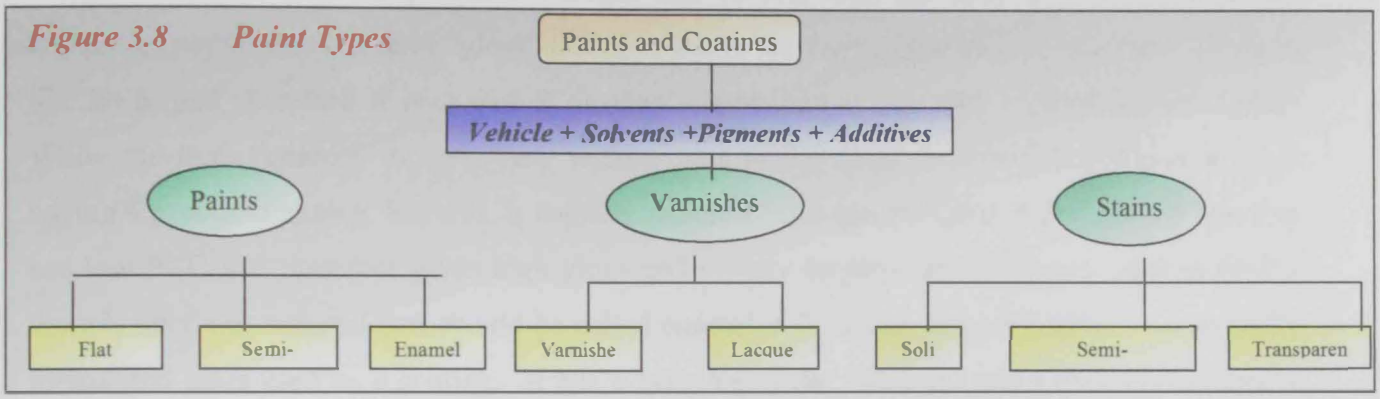
B.18. Catalysts:

Benzyl Peroxide is a commonly catalyst used for initiating polymerization reactions. It is of a low toxicity by oral route. It is a mild skin and eye irritator as a dust but not as a solution. For some people it is skin sensitizers. It is inhalation is mildly toxic.

3.3 Categories of Paints:

Once the chemical composition and role of each ingredient that build up the paint mixture are understood; it becomes easy to understand how the quantity and quality of these amounts play a major role in dividing paints and coatings into three main groups according to the following chart into: paints, varnishes and stains (figure 3.8).

Figure 3.8 *Paint Types*



3.3.1 Paints :

This first category of paints is the most commonly types used in the construction business to give an architectural surface to substrates whether they are interior or exterior. Exterior paints are usually paints with a low pigment load in order to give it to have exterior durability. The large binder content provides the film matrix required to with stand exterior conditions. The pigment volume concentration (PVC) is usually well under 40%. The low PVC (high binder) results in a strongly bond, highly resistant film possessing the following variable qualities: good weathering, glossiness, resistance to specific chemicals and abrasions. There types differ according to their ingredient composition amounts. On the other hand, interior paints which are also known by the name as flat wall paints are of a: high hiding power, a uniform appearance, resistance to burnishing, staining, chipping, yellowing and scrubbing. They are also of a good pigment binding properties such as being hard and smooth film as well as moderate in cost. (Michele and Arlene ash, 1978).But generally speaking for both interior and exterior paints, this category can be divided into three Groups: Flat Paints, Semi Gloss Paints and Enamels.

A. Flat Paints:

These paints are in the form of an opaque film forming materials that consist of high amounts of pigments, binders, solvents and low amounts of vehicle. The term "flat" describes a

film with low gloss, but this type of paint is best avoided because it invites confusion with the operation of flatting and an alternative word is "matt".

B. Semi-Gloss Paint:

This group of paints share shared properties between both flat paints and those of enamel paints. This kind of paints includes: sheen, silk, eggshell, semi-gloss and semi matt paints. The previous listing is an approximately decreasing order of gloss but there are no formal definitions for such paints.

C. Enamels (Gloss Paint):

Are paints with a high glossy surface that contain high amounts of vehicle and a low amount of pigments. The term "gloss" indicates the reflectivity of the surface of a film. Gloss is like color and therefore it isn't just a physical measurement but also a physiological factor. While the term "enamel" is now very widely used in the paint field which prevents it from having a precise meaning, but still, it vaguely means a high quality finish and a special one that has low PVC and therefore gives high gloss and usually requires an undercoat. But in reality there is only one material that should be called enamel is "vitreous enamel" which is a specially formulated glass used as a coating. It has a very high heat; chemical and solvent resistance is very hard and has an excellent color. The only disadvantage of these materials is their brittle nature and is expensive to manufacture because of it is fusing temperature, which is about 850°C. That is why in many applications where very high heat resistance is not needed "vitreous enamel" ", " stoving paints, which are often called "stoven enamels", have replaced ((R. Woodbridge, 1991).

Enamels are characterized by gloss- a result of low pigment volume concentration. Depending on the degree of glossiness, the weathering requirements, the pigment load, and cost limitations a myriad of trade sales and industrial enamels exist for just about any need (Michele and Arlene ash, 1978).

3.3.2 Varnishe:

They are mainly materials that are associated with wood substrates because of their ability to satisfy the demand for a clear finish, which in the case of wood substrates helps both, protect and display it is beauty. Exterior wood varnishes easily prevent weathering, but must also prevent UV light degradation of the wood surface because the resultant degradation loss of film adhesion (Michele and Irene ash, 1978).

They are defined according to the glossary of paint terms to be" a coating composition that is based on synthetic thermoplastic film forming material dissolved in organic solvent that dries primarily by solvent evaporation", therefore it is a non-convertible coating. Typical

varnishes include those based on nitrocellulose, other cellulose derivatives, vinyl resins and acrylic resins. These films can deteriorate in the presence of household chemicals and also due to human perspiration as well.

These clear finishes are also known by the name of "lacquers" and have the same composition of paint films but lack the pigmentation. Due to their lack of extenders and pigments they are a pure form of normal vehicles, which gives them the tendency to harden faster and be more highly vicious which can be a problem in application. Most varnishes are predominately yellow but the color of the liquid varnish is only a preliminary indicator of the dried varnish film. Initial color may tend to bleach or darken depending on the conditions of the exposure. The viscosity of the liquid is important to allow the satisfactory brush application. As these films harden by oxidation polymerization a skin may form on top of the liquid can which is then insoluble in the rest of the liquid (Yvonne dean, 1989).

In general the following types of varnish coatings are clear coatings with a high vehicle and solvent content but hardly if any pigments. They are used to protect the material of a substrate as well as for decorative purposes such as bring out the beauty of the material such as wood. They also have the advantage of ease in cleaning. The main difference between the different kinds of varnishes can be said to be in their drying mechanisms.

A. Varnishe

These coatings harden either by the method of oxidization of an oil vehicle or by moisture curing through air-drying evaporation.

B. Lacquer:

Generally, they can be defined as being clear coat finishes that are non-convertible that have an extremely fast drying ability through the mechanism of solvent evaporation ((R. Woodbridge, 1991). They are finishes that are either pigmented or clear which consist primarily of a hard linear polymer in solution. It dries by simple evaporation of solvent. Therefore it is possible to make a lacquer from any soluble linear polymer, such as chlorinated rubber, which is used in chemical resistant lacquers. It is important to know that the main polymer largely determines properties of lacquer. The two widely used types of lacquer are:

B.1 Acrylics Lacquer:

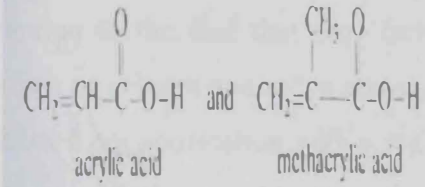
Acrylic paints are new comers to the paint industry, a product of modern technology. Their scope is virtually unlimited due to their very adaptable and versatile nature. They are the only new paints to have come on the market for centuries; they were introduced in the year 1962. They can be used as thick like oil paints or transparent washes like watercolor. They can be

applied to almost any surface. Their many attribute is that they rapidly dry and ideal used by those who need a top speed work rate (Ronald Pearsall, 1994).

Acrylic polymers are a family of entirely synthetic chain growth polymers, whose monomers are mainly esters of the unsaturated acids as shown in the figure below. Their full name is Poly Methyl Mythacrylate (PMMA) is a thermoplastic, found in the form of a glassy sheet known also as "Perspex" or "Diakon" (Yvonne dean, 1989). Methyl acrylate ester of higher Alcohol that gives softer more flexible polymers and softens above 150°C.

Figure 3.9 Acrylic Acid and Methacrylic Acid

mers are mainly esters of the unsaturated acids:

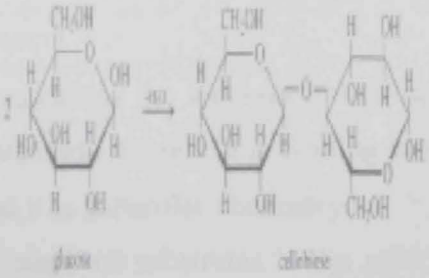


Data From J.Bentley and G.P.A Turner1998

B. 2 Nitrocellulose Lacquer:

Are lacquers that aren't totally synthetic, due to their cellulose base that is not made but rather found in nature where it forms about half of all the cell wall material of wood and plants. Cotton is almost pure cellulose while wood pulp is another major source. The cellulose molecule consists of a large number of rings of atoms joined as shown. The three-hydroxyl groups per glucose ring they may either be esterfied by organic or inorganic acids, or etherified with suitable Alcohols. In this way many useful polymers for paint making are produced (J.Bentley and G.P.A Turner1998).

Figure 3.10 Glucose



Data Obtained From: J.Bentley, 1998

3.3.3 Stains and Their Types:

Again in these kinds of paints there are several kinds that can be obtained according to the amounts of each ingredient that go into their formulation. They also differ in their method of applications.

A. Solid Stains

These stains are usually water based and contain much more pigment then any other kind of stains. In a way they resemble dilute paints more than they do other stains.

B. Semi Transparent Stains

These stains have a larger pigment and solvent content than that of transparent stains. They are not to be wiped off after application but rather left to dry. Semi transparent stains are used in exterior applications and are made up of two coats but they don't require a clear topcoat.

C. Transparent stains:

These stains are transparent due to the fact that they have no or just little vehicle or pigments, but of a very high proportion of solvent and a dye additive. In this kind of stains, they are to be wiped off after a few minutes from application with a rag leaving whatever of the stain that has penetrated the substrate. It is usually known that stained surfaces are later coated with a clear finish, varnish, to bring out the color and figure of wood and produce a durable easily cleaned surface.

Categories: preparatory paints like primers and undercoats; topcoat paints, of which gloss and emulsion are examples; and special purpose paints such as masonry and textured paints. Paints are either for interior use or exterior use while some is used for both interior and exterior surfaces as well (John McGowan and Roger Durben, 1990)

3.4 Surface Preparation:

In the previous sections of this chapter we have considered the general principles by which all paints are formulated. All these paint and coats are applied to a substrate to produce a paint system consisting of: substrate, primer, undercoat and topcoat. Whether or not the final result is satisfying depends on how these layers adhere together, how they perform individually and where the weakest link is present.

J. Bentley refers that; sometimes the weakest link is at the substrate –primer interface (e.g. poor adhesion), or in the substrate it itself (e.g. Rotting wood). Therefore it is necessary to consider the substrate it itself and it is particular chemistry.

The surface preparation stage of substrates is the most important stage of the coating process success. Before the painting of any surface with any type of coating it must be clean, dry, and smooth and stable (W.B. McKay, 1991). If this is not done, then, the paint will be adhering to loose particles of the solid substrate, meaning eventual failure defects that will appear on the surface sooner or later (Yvonne dean, 1989). To avoid such assured failures in the coating system, certain steps are to be made: moisture content testing and the removal of old material.

3.4.1. Moisture Content

It is common for most substrates, which have not fully hydrated, especially in the case of plasters and renders, to undergo additional moisture loss. For this reason certain checks are to be made on the moisture content of the surface to be coated before any layer coating can be used to cover it. This can be done through one of the following methods: With the aid and usage of hand-held instrumentation, Sealing off an average area of 300 sq.mm and taking measurements at it is center with moisture sensitive papers, Usage of a hygrometer device, this devise can be used for any large-scale finish that involves wetness.

3.4.2. Removal of Old Materials:

For this method any old coatings are to be removed using one or more of the following surface preparation methods: burning off, solvent and chemical removers, physical remover of paint films and removal of fungal and algae growth on paint work and related coatings.

A. Burning Off:

Existing paint films can be removed by heat treatment. But, great care must be taken into consideration while this method is being used. Blowlamps can leave burn marks if used carelessly. Where as, hot air paint film softeners are less likely to mark timber substrates.

B. Solvent and Chemical Removers:

These solutions can be very hard and chemically aggressive and not to be used in confined closed spaces that are not well ventilated. In cases where such solutions are used, surfaces must always be washed clean before a new coating layer is applied to the substrate.

C. Physical Removal of Paints:

Timber sanding methods produce good results as loose fibers are removed from the wood substrate. Sand blasting techniques are also very effective as the coarser the particles used the higher the rise of grain as a softer pulp is removed. But it is also important to know that it is important to test samples before it is applied on a wide range.

D. Removal of Fungal Algae Growth on Paint Work and Related Coatings

This is a problem especially in microenvironments, which foster biological growth. A 5% sodium hypochlorite can be used in conjunction with also another 5% trisodium phosphate aqueous solution (non-ammonia containing laundry detergent).

The surface can be first tested with a drop of 5% sodium hypochlorite solution, if it happens to bleach, this means microorganisms are present. The surface should first be washed with the 5% trisodium phosphate aqueous solution, and then thoroughly be washed off with clean water and then one part sodium hypo-chlorite, for 10-15 minutes time period. Then for the

final step, surface again is rinsed very well for the final time with clean water. Then it can be painted but after being absolutely sure the surface is dry (Yvonne dean, 1989).

3.4.3 Surface Substrate Preparations for Different Materials:

Now after the old surface has been cleared of it is old coating of paint, we will start to study how to prepare each substrate to receive the new coat of paint as though it was a new surface. But this will differ according to it is original substrate material, which will have a need of different preparations.

A. Timber

Almost all timber used for building construction and decorative purposes have to go through a certain form of preparation before it can accept any paint coating. one of the chief problems accompanied with timber usage is that it absorbs moisture from it is surroundings and this creates a rich environment for different life forms. If timber is dead, and there is no growth then these living organisms, whether insect or fungal, will start to break down the structure so it can return it to the natural food cycle. But there are different methods to deal with moisture according to whether it is new or previously painted timber.

A.1. Moisture Content

In the first case of dealing with new wood, moisture content should not exceed 15%. Before coating wood substrate it must be cleaned, smoothed, dust removed, any grease cleaned off with white spirit and nails punched down. Then the following specifications are that it should be "knotted, primed and stopped"; and it is very important that these labors are executed in order. Careful treatment of knots is essential; loose dead knots, and those, which are particularly resinous, should be cut out and replaced by sound timber. Other knots should be coated with knotting, to prevent the exudation, meaning to discharge or emit, of resin in two coats allowing each coat to perfectly dry. In the next step of wood surface preparation, the whole of the surface is then primed with a good quality primer. A lead-based primer is best for exterior work. A lead-based paint should not be rubbed down dry for the dust is toxic; instead the wet method using water and an abrasive paper must be used. Note: lead paints are only to be used out side and they should not be sprayed because they are poisonous.. A primer for hardwoods should be thinner than that used for softwoods. The next operation is to stop or fill in any cracks and nail holes with a stopping, a type that consists of red lead and gold size. Next 2-undercoats and the finishing coat are applied; the undercoats are rubbed down with fine abrasive paper after drying. It is important to note that in such cases at least 2under coats are required, and 3-4 are required for exposed areas. The under coat can either be an oil or alkyd resin type in any kind of finish except matt which is to only be used for interiors.

A.2. Previously Painted Wood:

If previous paint coating has not degraded in an excessive way it will only be necessary to wash the surface and rub it down with water proof abrasive paper dipped in water. Any bared wood should be re-primed before a painting job may be preceded. When the required painted surface is in a bad condition or the film is very thick a fresh start should be made by removing the whole of the paint. Removal as has been mentiId before earlier in the chapter can be done by burn off or by the application of a solvent, which is brushed on to soften the paint and followed by scraping. The now bared wood is then painted as mentiId for new wood substrates (W. B. McKay, 1991). It is important to know that it is undesirable to mix the two processes on the same job; therefore, a decision must be made before starting in the operation, between rubbing down and completely removing the old paint coat.

From all of this we come to the conclusion that timber surface preparation can be concluded in it being: clean, dry fill up of cracks or nail holes with putty, all knots and sap streaks should be sealed. And to prevent of nail heads from showing they are countersunk and filled with putty before the first coat is applied. In cases of painting over previously painted surfaces all loose scaling or peeling paint must be removed and there cause should be determined as well as corrected before repainting (J. K. McKay, 1992). The second major problem that we are faced with when dealing with timber in construction is that all untreated timber will bleach and eventually turn gray under the effects of ultra-violet light rays. Very few timber species stay stable in these conditions, as the ultra-violet rays tend to destroy the lignin content in timber. When this binding material is lost or degrades it causes the loosening of cellulose fibers to be left and surface delaminates.

B. Metals (Iron and Steel)

The preparation of steel surfaces is very critical, and however good the surface is cleaned from impurities, initial corrosion, and initial protection must be carried out as soon as possible as preparation and a certainty which must not exceed a time period of 4 hours after cleaning. Other wise, surface coatings will be adhering to an increasing and thickening oxide layer rather than the required steel substrate before it is delivered to site

Corrosion is what is responsible for most of steel damaging and their expensive maintenance bills; therefore it is always recommended to have them galvanized wherever possible. Like with all coating surfaces previous preparation is a necessity. In the case of ferrous materials this includes removal of mill scale and rust. While workshop preparation can include pickling in hot dilute hydrochloric acid to remove the scale, rust and phosphating. A phosphate dip provides good resistance to rusting. On site, there are certain liquids that can be

used which inhabit to rust (Yvonne dean, 1989). Rusting metals should be wire brushed and all rust flakes and loose particles should be removed.

B.1. General Preparation:

Solvents are used to dissolve oil and grease, and surfaces should always be well rinsed after application. Aggressive ***alkali cleaning*** will take off the old paint and if it is used it should be thoroughly rinsed afterwards from the substrate. Wire brushing and scraping with metal tools is an unsuccessful method for preparation of metals. While blast cleaning is much more effective in removing both dirt and corrosion. In addition to that this method also can give the metal surface more topography that will help in giving more adhesion. Pickling and acid etching will remove scale. Flame cleaning is also used, but to evaporate moisture from the face of the metals and can help detach light corrosive deposit is, but it should be used with great care. For it could affect the strength of metals locally to the touch .By raising metals either to their melting temperatures and causing possible re-crystallization to occur or possible strength loss on metals below a 5mm thickness. Priming can be carried out on metal that is still warm but not if it is still too hot.

B.2. Atmospheric Parameters:

In the surface coatings of metals it is fundamental that the surface is dry. Any moisture on the face of the metal may be trapped, which initiate corrosion below the paint film and cause might inter granular corrosion, which can cause flaking-off of paint and spalling of finishes. In it is turn may generally lead to pitting in the surface of the material. To avoid condensation on the face of the metal, metal temperature must be above that of air-dew-point.

B.3. Priming:

Priming is that step that should quickly follow after the preparation of the metal surface and that should happen within no more than 4 hours of that process. The reason for this is due to the nature of metal that has a great surface area available for corrosion.

It is important to know that the priming coat has to be good enough to resist normal weathering conditions for some time. Especially when steel is in a primed condition and may stay exposed because frame structures are often erected before finishing coats.

In general all surfaces must be clean and dry and free from wax, oil or grease. Steel must be coated with a rust inhibiting primer. Galvanized surfaces must be either treated with a chemical, wash or primed with a special primer before painting. Aluminum surfaces should be etched with a special preparation before painting (R. Lambourne, 1987). It is also advisable to carry out surface coating if the air temperature is above 5°C and the relative humidity is below 80%.

C. Plasters, Cements, Concrete and Brickwork Mortar Surface Preparations:

The following section discusses the general points that bond plasters, cements, and concrete and brickwork mortar. We must understand that all these for materials set by the hydration mechanism, meaning the chemical reactions with water and which provides new compounds. Hydration rates are usually slow and are not to be hurried if we intend to get the required results. Any method to speed the drying process will only result in taking away the moisture, which is a necessary assistant for the hydration process and will result in leaving the surfaces of the materials more friable and of poor results. The proper approximate hydration time is 5weeks for a 25mm of wet construction.

The materials used in wet construction often have salt impurities, which after wetting with water re-crystallize and seen as efflorescence, which are opened up and revealed on the surface. Depending on the types of salts present it will be decided whether the final finishes will be a hard glassy skin or a more recognizable white fluffy compound. Efflorescence that have developed and appeared is likely to cause damage to the new coatings and should be removed and then the surface is to brush down every few days until the reaction ceases (Yvonne dean, 1989).

C.1. Plaster and Stucco:

Since most paint films are compatible with plaster, it is a rule that plaster and stucco should be completely dry and cured before any paint coat is applied on them There are significant differences between types of plaster used that may effect the performance of coatings. Plastering can be done with lime plasters or with calcium sulfate plasters. It is important to know that painting technique slightly differs for each method (J. K. McKay, 1992).

C.2. Calcium-Sulfate Plasters:

When damp these plasters do not have the same effect on paints as lime plasters just mentild. But still moisture still can't be tolerated in case of painting, and a certain drying out period is required. The painting methods are similar to those for lime plaster with the exception that alkali-resisting primer is not needed. Cement paints are not to be used with calcium-sulfate plasters (W. B. McKay, 1991).

C.3. Concrete Surfaces and Cement Renderings:

Such substrates are alkaline materials in nature; therefore oil paints can't be used, because these materials are known to be compatible. If they are used then in this case a "saponification reaction" occurs, where paint films effectively turn into soaps. To avoid such situations entirely, only finishing coats designed for such backgrounds are used and they are classified to be masonry paints

C.4. Lime Plasters:

Are alkaline plasters and if damp will attack oil paints, Prussian blue and Brunswick greens pigments. Therefore these paints and pigments should not be used in paints on damp lime plaster. The best method that can be achieved in such cases is to use a temporary coat of soft distemper. But, in dry background construction, and when plaster has been dried out for a few weeks then an oil-bound distemper is required which forms a reasonable surface for decoration with the paint or a flat oil paint. If the lime plaster surface is left until both it and the backing wall are totally dry an oil gloss paint finish can be given but under the condition that an alkali-resisting primer has been used. Cement paints are also applicable on plasters only if they have not been gauged with a calcium sulfate plaster.

D. Masonry and Cementitous Substrates:

Among the most widely encountered surfaces in buildings are plaster, concrete, external rendering and brick. Although these are individual materials with their own characteristics they also have a number of general similarities, which influence coating formulation. Of particular significance are alkalinity, the porous friable nature of the surface, and the general consequences of moisture and it is interactions with the substrate.

D.1. Implication of Moisture:

Water is often present in large quantities in new building materials (e.g. concrete, plaster, bricks...etc). This is very true especially with hydraulic cements and plaster, but will also result from the storage of materials in the open during construction. Surface created from "wet" materials of construction may require an initial coating of very high permeability to allow drying out, though subsequent redecoration with less permeable coatings is possible.

Moisture content is suitably quantified by quoting the relative humidity in contact with the surface. According to BS standards surfaces are divided into 4 groups according to their equilibrium moisture content:

Dry -< 75% RH

Drying - 75%-90% RH

Damp - 90%-100% RH

Wet - 100% RH (with visible moisture content)

Wet surfaces are very difficult to paint, but damp and drying surfaces can be coated with emulsion paints, which are usually formulated above the critical PVC to increase permeability. (R. Lambourne, 1987).

D.2. Cement and concrete:

Cement as a component of concrete finds a very wide application in all types of buildings. Such wide spread use reflects the attraction of this material of economic development which is relatively cheap, can be molded or cast, will stand high compression. Iron or steel concrete reinforcement also allows the carrying of tensile loads. Coating requirements of such products are largely dictated by the nature of the cement matrix through surface appearance will be modified by the presence of fiber.

Many architects would maintain that concrete does not require painting, but apart from aesthetic aspects there are situations when a coating can prevent water penetration and reduce attack by carbon and sulphur dioxides.

D.3. Coatings and Formulating Practice for Masonry and Cementitous Substrates:

Due to difficulties of classifying coatings in general which is related to the fact that classification represents a particular point of view, which may seem arbitrary when seen in different context? BRE Didest 197 lists the major coatings established in the field of masonry and Cementitous substrates into broad categories of water-based and solvent based paints and coatings. In these categories there are other groupings such as those depending on the physical nature of the binder (solution, dispersion, emulsion, etc.) or the chemistry, including a division into 1-pack or 2-pack products. The following sub sections below highlight some of the most important and representative groupings, but with no attempt to be comprehensive.

- ***Sealers And Colorless Treatments:***

The porous and sometimes friable nature of masonry surfaces has created a market for water repellents and in some cases for sealers to act as primers prior to painting.

- ***Water Repellents for Masonry:***

These materials are intended to improve resistance to rain penetration with minimal effect on appearance. They function by inhibiting direct capillary absorption, but do not normally provide a continuous surface film. Properties of interest include resistance to water penetration, water vapor transmission rate (permeability), resistance to effloresce and longevity of the effect. Such treatment will not necessary decrease water uptake through cracks, which may in fact increase as the treatment causes more water to run across the surface. Waxes, oils and metallic soaps have been used as the basis for water repellent but these have tended to be supplanted by silicone resins in various forms. These resins are available in both water or solvent based forms; where as the water base are highly alkaline.

- ***Sealers:***

Masonry sealers also know as stabilizers are intended to consolidate friable surfaces. Typically they are based on alkyd solutions carried in white spirit; a tung-modified alkyd is advisable in order to improve alkali resistance; tung-phenolic resins are also suitable. Paradoxically, some masonry paints, including the emulsion type do not adhere well to a continuous stabilizer film. Therefore if the surface is sound then a stabilizer should not be necessary.

An alternative to alkyd or other resin solution is to use very fine particle size latex at relatively low concentration; styrene acrylic lattices and acrylic lattices have proved suitable.

- ***Alkali Resisting Primers:***

These primer products are associated in particular with the masonry market, which is of the alkali- resistant primer designed to hold back the alkali attack on essentially dry alkaline substrates. Although normally used below oil finishes they sometimes can be used to improve the adhesive performance of emulsion paints and on plaster surfaces. Variants specifically preparing plaster are also marketed.

Alkali-resistant primers have been successfully formulated for many years on tung-phenolic and tung-coumarl resins. Resistance may further upgrade with Isomerised rubber. PVC and volume solid contents are typically around 30% and 50% respectively.

Waterborne primers can be formulated on acrylic resin dispersions. To aid penetration, the latex should be of fine particle size and primer pigmented to a low PVC and solids content.

D.4. Paints Based On Cement:

The market for "cement paints" which were once widely used has sharply declined. It is usually used as an exterior paint because of their specific advantage in being applicable to wet surfaces. These paints are based on white Portland cement with further additions of titanium dioxide and colored pigments as appropriate; they also require agents to control flow and structure.

The rough surface of cement paints encourages dirt pick-up and algal growth. They will erode rapidly in polluted acidic environment. Interaction between cement and gypsum precludes their use over their substrate, they are supplied in.

3.5 Health, Safety and Environment:

Before starting any paint job it is necessary to consider a few health and safety messages. Like many household products paint is made up of chemicals and can be hazardous if not

properly used. Paint is a blend of pigments for color, resins for binding power and other additives dissolved in solvents. While over the years paint manufacturers have found substitutes for potentially hazardous ingredients, solvents are still a necessary ingredient in some paints. Recognizing this has manufactures clearly state the potential solvent hazards on paint labels. It is very important for paint users to read warning and caution notes stated on paint can labels before starting any paint job.

This following section brings together some issues, which have been mentild, earlier on in this theoretical literature report. These are concerned with the health and safety of individual and the individual and the protection of the environment from all the aspects of paint preparation and usage.

3.5.1 Personal Health And Safety:

A wide range of materials is used in paint making and a variety of chemical reactions occur in both the preparation and use of paint. It is essential to think of all the ingredients as chemicals, which have hazards, associated. For instances, short term exposure to acids and alkalis can cause corrosive burns, a variety of materials can cause skin and eye irritation, and dusts and vapor can give rise to lung irritation. Inhaling higher levels of solvent vapor can cause short-term intoxication effects and extended skin contact can cause disorders such as dermatitis. Longer-term exposure to a number of chemicals can result in cumulative harmful effects or sensitizations.

Sensible general precautions and some with extra care because of specific dangers can prevent many of these dangers. Good general practice is to avoid unnecessary exposure to chemicals. Contact can be made with skin and eyes during handling with the lungs by breathing dust or vapor and by swallowing after transfer from the hands. This can be prevented by control of the work environment and by use of protective clothing. Basic precautions are always to work in conditions of good ventilation to use some form of skin and eye protection and to wash before eating or drinking. The strictest precautions are those required against cancer causing chemicals though this are not likely to be present in paint supplied for application.

Precautions during the application of paint depend on the methods of application and curing used. Minimizing contact with the solvent vapor requires air extraction; spray operations will be carried out in spray booths where contaminated air excess spray droplets are treated. For some materials such as isocyanate, spray operators may be required to wear air-fed hoods. Factory environments are now regulated for all emissions including vapors, dusts, liquid and solid wastes and these must be monitored and controlled.

Substances already noted as hazardous earlier are lead and chromate pigments, solvents, lead driers, formaldehyde and isocyanate. Users also need to be aware of the toxicity of

fungicides and algaecides, the general unpleasantness of unsaturated monomers and finally the hazards of low molecular weight amines and epoxides. It is also important to note that those with allergic conditions may be restricted from handling isocyanate and anhydrides since these are known to be respiratory sensitizers.

3.5.2 Written Information On Hazards:

In much standard regulation guide manuals, dealing with chemical hazard information at all hazardous, require that all hazardous substances whether paint or paint ingredients, should be properly labeled when they are supplied, or consigned by road. Additional regulations cover international sea transport by sea, air, road and rail. Before supply and transport, substances must be assessed and depending on the outcome, containers may have to be labeled as " flammable", highly flammable", " extremely flammable", "irritant" "harmful" " corrosive" "oxidizing" "toxic" "very toxic" labels may be necessary. Labels identifying danger to the environment and marine pollutants may also be required. Paints must be supplied with instructions for safe use. It is also necessary to highlight the need for segregated storage of paints and thinners but in all cases it is bad practice to store in the work place. Recommendations for disposal of waste paint and used containers are also compulsory. Regulations concerning labeling for the users of paints require the use of both "risk phrases" relating to particular hazards associated with the material and "safety phrases" indicating required safety precautions.

Finally, material safety data sheets with property and composition information are required for users. Mandatory headings include identification of the material and the company supplying; composition, or information on the accidental release measures; handling and storage; personal protection; chemical and physical properties; toxicological information; disposal considerations and transport information. (J.Bentley and G. P. A. Turner, 1998).

A. Flammability/ Combustibility:

Some paints contain flammable and combustible ingredients. In such cases, the label will have the words "warning flammable or "caution combustible" in a clearly marked area. So reading label before opening a can of paint is required. If paint is flammable or combustible the following precautions are to be taken into consideration:

- Provide as much ventilation as possible to disperse fumes by opening doors and windows but it is recommended not to use fans in such spaces to avoid the risk of creating sparks.
- Elimination of all sources of flame, sparks and ignition. Put out pilot lights by turning off the gas and not relight until well after the room is free of fumes.
- No smoking is to be allowed while working with such flammable materials

- Don't use electrical equipment, which might spark while working in flammable or combustible paints.
- Light bulbs are not to be exposed to sudden breakage
- Immediate Clean up of spills. Insurance of safe disposal of spillage waste and solvent saturated clean up materials.
- Containers are to be kept tightly closed when not in use.

B. Solvent toxicity:

Some paints contain organic solvents. These are usually oil base or alkyd paints, some times used on woodwork and areas where a high gloss or used to dissolve and/or disperse paint ingredients. Overexposure to solvents can have toxic effects. These definitions may be helpful:

- Toxic material –A materials that can cause illness or injury when not used properly.
- Over exposure occurs when there are enough toxic materials in 1s body to cause illness or injury.
- Acute effects is and illness or injury from one time overexposure to large amounts of toxic materials. These are of immediate effect.
- Chronic effects and illness or injury resulting from repeated prolonged over exposure to toxic materials. Chronic effects may not be noticed immediately to provide warning of over exposure.
- Allergic reaction is the hypersensitivity to any ingredient not generally known to cause reactions. Reaction may be severe in some cases.
- Routes of entry mean the methods or routes, which toxic materials can get into the body. They are inhalation, ingestion and contact

C. Safe use:

- Like many household products same paints can be hazards unless used in the proper way. Over exposure to many products even some foods can have toxic effects. Simple common sense practices can take hazards out of using household paints.

C.1 Inhalation

- Open all windows and doors to get ventilation. Do not use product in deep basements as solvent fumes will accumulate near the floor and be hard to remove.
- If eyes become watery or a person begins to feel dizzy or nauseous they are to leave work area immediately and get plenty of fresh air. If discomfort persists or breathing difficulties occur medical help is to be obtained.
- If u can't get enough ventilation in work area uses a respirator. Which is a breathing device designed to clean the air being breathed.

C.2 Ingestion

- Containers are to be kept close when not using them
- Paint products are to be kept away from the reach of children.
- Due to variation of paint ingredients on methods on how to deal with them it is important to read the Labels on paint cans before the can is opened
- If paint is swallowed fir staid rules are to be followed according to instructions on the label and a doctor or clinic is to be immediately contacted.

C.3 Contact

- Wear a long sleeve shirt and long pants when painting
- Wear butyl-rubber gloves. Not only will this protect the skin it will make it easier to clean up later.
- Wear splash goggles
- If you get solvent based paint on your skin wash off immediately with plenty of soap and water.
- If you get solvent based paint in your eyes flush the eyes with cold water for 15 minutes and obtain medical treatment.

C.4 Storage:

- Some paints are flammable or combustible and require special storage procedure
- Follow label instructions for storing
- Before storing make sure containers are tightly sealed
- Do not store flammable or combustible paints near heat sources such as furnaces water heaters and space heaters.
- If only a small amount of a solvent base paint remains it is best to dispose of it rather than store it.
- Do not store or re-use empty containers.

D. Protecting the Environment by Good Formulation

Reduction in the volatile organic Content (VOC) of coatings, contributed by the solvents presence, is now required because solvents, particularly hydrocarbons contribute through a reaction chain to an increase in ground level pollution (Photochemical Ozl). The hole in the ozl layer in the stratosphere concern the formulators is the remove of Lead, Chromium and Cadmium, which are long term environmental pollutants in paint residue.

Complaint coatings are those coatings, which meet legal requirements for low VOC or requirements arising from voluntary industry agreements. Complaint coatings include powder coatings, unsaturated polyester and radiation-curing finishes, which all contain little or no

solvent. In addition alkyd, polyester and acrylic coatings can be made at high solids with reduced solvent or in water base solutions or emulsified in water using different techniques. Reformulation of solvent based coatings to make them water based requires awareness of special water properties.

While VOC laws and agreements define maximum solvent levels, voluntary eco-labeling schemes, provide incentives to formulate to a higher "green standards". Included in these schemes are targets for maximum of 1% of aromatic solvents (Xylene and Toluene) in decorative paints (J.Bentley and G. P. A. Turner, 1998).

E. Toxicity and Environmental Pollution:

In recent years it has become evident that many of the solvents in common use represents a health hazard, and legislation has been introduced to control their use. In addition, even with low toxicity solvents their odor may be unacceptable both in the working environment and the vicinity of manufacturing and user plants. Solvent emission into the atmosphere can be controlled by the use of afterburners on extraction systems or by recycling.

Studies of the toxicity of solvents as with any chemical compound cover a comprehensive range of standard test procedures, including animal testing for toxic effects arising from skin contacts with the liquid, exposure to vapor at a range of many years on the effect of exposure of workers in most industries to the chemicals which they use. These data, which are constantly being revised as more information is being obtained, are used to define acceptable working conditions for those exposed to solvents in their daily work.

The most commonly applied limit on solvent concentration in the atmosphere is the "threshold limit value" (TLV). This is usually applied as a time weighted average value, which takes into account the period that an individual may be exposed during their working day (e.g. 8hours). Therefore the TLV gives the average concentration that can be exceeded for a short time period if most of the time the individual is working in an exception to this is if a "ceiling" value for a given material has been defined. In this case the concentration of the material must not exceed the ceiling value if a health hazard is to be avoided. Fortunately, few solvents come into this category. Some TLV are given in table in appendix II (R. Lambourne, 1987)

3.6 Summary:

The previous chapter was dedicated to the detailed discussion of paint material as an example of manmade polymeric material. These materials have many purposes and uses to which we may relate the large market of available paint types, textures, colors...etc. In it is turn this can only mean that though they are all basically made up of 4 main ingredients (vehicle, pigments, solvents and additives) but with different percentage composition to which we may

relate the variety of available paints related to design requirements and decorative purposes. But basically they can be divided into water based paints or oil based paints according to the base of the solvent base it is prepared with. There are 3 main types of paint polymer materials: paints, varnishes and stains. Again type of paint is specified with the composition % of each ingredient of it is mixture content

Since the method and quality of paint surface substrate material preparation has a great effect on the output result of any painted surface regardless of the substrate original material, some consideration with detail was given to this subject with respect to general issues and specific 1s according to original substrate material. But generally we can say in order for any surface to accept paint as a finishing material without defects such as chalking, blistering, cracking,... etc. it is important that the substrate should be clean, dry, grease free and in good condition.

The final part discussed health and safety of environment in which paints are used. Paints through studies have been known to extract toxic chemicals and fumes during the drying process which takes place through evaporation, oxidization or polymer reactions. With this information in hand it was found that safety and protection knowledge was recommended to all whom deal with paint whether in direct or indirect way. The importance of knowledge surrounding paint hazards and toxicity is related to the hazardous effect it can have on human health if miss-handled or exposed to certain paints in large amounts. Over exposure to paint causing hazards can be through: inhalation, ingestion, skin and eye contact. In some cases this might lead to severe damages of body organs according to the range of hazard the material is connected to. These points are going to be discussed in the following chapter with greater detail based on end user opinions and experimental lab work based on scientific background and data information.

Chapter 4:

Fieldwork & Experimental Methodology

4.1 Introduction:

To achieve the objectives of the study, a wide range of data was required. Some information was available in published and unpublished official documents, which has been adopted and applied in chapters (two and three). How ever, others had to be collected by carrying out empirical work in the form of field survey and conducting lab experiments on various chosen paint samples.

Several visits were made to different building types in all three main cities of the emirate of Abu Dhabi and they are: Abu Dhabi, Baniyas and Shahama. This survey was carried out using personal observations and interviews with users whom tend to spend an average of 8 hours/day with in different spaces of buildings. To narrow down the study both educational and low cost housing were chosen to apply on our thesis study. But before the visits were made, a questionnaire was conducted to help the purpose of the visit and give strength to personal observations and conclusions.

In general the chapter consists of two parts and six main sections. The first section (4.2) identifies the purpose and the objectives of the fieldwork survey, and is followed by a sample of the conducted questionnaire that was distributed on different building type building users. The following two sections discuss sources and methods of data collection, which were used to cover the fieldwork. The fourth section (4.5), dealt with the questionnaire survey and preparation for final analysis through translating data into numerical graph charts, which make observation and understanding much easier and effective. The design of the questionnaire, sampling procedure and the chosen techniques for information gathering, collecting and analysis are also included. While the second part of the chapter (section 4.6) is donated to experimental lab tests done on various types of paint samples and their analysis, in addition to the techniques and methods used in order to obtain these results. The final section (4.7) is the summary.

4.2 The Purpose of the Fieldwork:

The purpose of the fieldwork was to collect data and information that would identify the most important disease and symptoms problems of which users are most likely to come down with or initiate if already affected. This provided the essential basis for the formulation of selecting most suitable and less harmful finishing paint materials both from principles and design criteria point of view. To achieve the purpose of the fieldwork, the following objectives were identified:

1. To gain the background knowledge and up-to-date information about the physical characteristics of the study topic, this might affect expected result criteria.
2. To provide a better understanding for the authorities and end users in issues concerning selection of paint used for building finishing materials with the least harm on human

health with relation to environmental aspects within the UAE in general and emirate of Abu Dhabi in specific.

3. To determine the main diseases and symptoms those appears or are influenced due to the use of paints in different buildings constructed by works department.
4. To investigate to what extent these finishing materials can affect human health and what diseases they can cause or fairly influence.

4.3 Sources of Data:

The fieldwork data was collected from two principle sources. The first was official sources, through the following bodies involved in material specifications:

1. Works Department- Abu Dhabi
2. Planning Department-Abu Dhabi
3. Jotun Paint Factory
4. Urban Planning Institute

The second source was the occupants (end-users) of the different building types constructed by various government departments especially the works department. This source was covered through the survey that will be discussed in section (4.4.2)

4.4 Methods of Data Collection

Two methods were used for collecting the required data and information. The first was literary reviews of the documentary sources, which were collected from the authorities and paint manufacturers, and second was the field survey that covered the case study.

4.4.1 Reviewing Documentary Sources:

Part of the information required was collected from published and unpublished studies and reports related to the subject and area of concern. This information, which could not be obtained by other methods of survey, provided evidence, which could be used for comparative analysis of the findings of the field survey and interviews. This information included:

1. Finding out the diseases and symptoms taken into consideration and which are most commonly present in the community and how use of paint finishes to spaces may influence or effect end user health.
2. Detailed information of the number of affected end users who were taken as samples for the fieldwork survey.
3. Investigation of the main causes of such diseases and symptoms to appear.

4.4.2 The Field Survey:

The field survey was to obtain the main source of information to identify the current key issue diseases and symptoms. The methods, which might be adopted, therefore deserve careful study. The possible methods of data collection through the field surveys are varied. They include mail, telephone, personal interview, fax, Internet. Given the research topic, the nature of the study area, the characteristic of the sample in different building types and locations, the size of the sample and the available facilities for the surveyor, personal interview was selected as the most appropriate method to achieve the objectives of the field survey. The most important reasons were:

1. Personal group interview procedures were the most effective way of enlisting cooperation of the respondents (residents, students, educators).
2. The reactive possibilities enhanced in the personal interview method helped the less literate and non-serious interviewers better understand the survey and the aim behind it. Therefore, some of the questions were better understood and given more as well as appropriate answers.
3. Personal interviews provided multiple methods of data collection, including observations, visual signs and cues, and self-administered sections.
4. The author was the only person familiar with the kind of required information material needed to achieve the main goals of the research.

However the main disadvantages of such a data collection method was that the total data collection period was longer than expected if other methods had been used. For this reason the research only was able to cover two building types instead of four as was intended before the start of the research study.

The field survey was carried out through different phases: observational survey (medical records and studies), interviews with different end users (residents, students and educators) and the questionnaire survey. The first three phases are discussed in the following sections, while the questionnaire and the preparation for the analysis are discussed in more detail in section (4.5).

A. Observational Survey:

Medical records and studies were one of the main methods on which the survey depended for recording information, particularly to provide a clear understanding of the existing pressing issue of increasing numbers of patients requiring allergy treatment in the E.N.T((Ear, nose and throat clinic) in government hospitals and most likely in private clinics as well. It was essential in some cases where subjects were incapable of providing information or information was unclear in some cases. It was also important as a complimentary technique to the questionnaire survey to provide a whole picture of the existing problem being faced on daily bases. The observational

survey covered many key issues and problems that were unknown or discussed before. These features included:

1. En-lighten on the reason of the most common disease undergoing medical treatment in government hospitals or clinics without understanding the back screen causes.
2. The discovery of lack of knowledge in effect of finishing materials either by authorities and end users to the effect of these materials on their health in the environmental circumstances of UAE.
3. Hardly any official standard specifications were available for any material not just paints used in construction of the various types of buildings. Those that were used were adopted from foreign countries, with totally different climates, cultures and environments in total. The observation survey was carried out using pre-planned tours by car for the distances between each three cities selected for the case study ranged 30-50km.

B. Interview with authorities and End Users for Public and Residential Government Buildings:

This phase of the survey was based on discussions with people in authorities whom are involved either directly or indirectly in decisions related to material selection for building construction or allowing trading or importing into the country. They included those working in Abu Dhabi works department, Jazeera hospital E.N.T and Skin therapists, Jotun paint manufacturers and finally different type of end users of different building types.

The main purpose of these interviews was to identify the different aspects and points of views of different group authorities and others. This was to identify the different involvement of these groups and how their views and decisions affected the direction of decision makers whether in the works department or any other local or international authority. Among the people interviewed were engineers, architects, doctors, government head authorities and personnel's, residents, students and educators. One of the main advantages of this action was to gain a general view of public opinion and of groups that are responsible and will be for future planning and decision-making in planning of constructions.

At the private level, discussions and interviews were carried out with directors and head authorities in the works department who are responsible for construction of most of government buildings on the local level of the emirate of Abu Dhabi. The main aim was to identify their interests and opinions on how to influence research study for materials used in construction within the country and how that could be applied in a legal way in practice before any more buildings are constructed with human welfare and health being the main consideration.

To conduct these interviews, the author had to give advanced warning of the visit is and take scheduled appointments or through personal contacts, which helped in collecting the

information, needed within the available time. During these interviews list of points prepared in advance was used to help make maximum use of the meeting. Despite some difficulties faced by the author as discussed in appendix 1, the responses of these interviews were reliable and helped to identify to what extent the problem was starting to be noticed but no solution was yet applied or given attention to.

The interviews carried out with end users were of great help in collecting required information which was put into consideration during carrying out both the survey and experimental laboratory tests. Special consideration was given to the study main aims and goals. These considerations helped narrow down the search to the most pressing issues in form of diseases and symptoms faced daily without really understanding the reasons that are behind them or what causes them or how to deal with them and hardly even come to prevent them.

4.5 The Questionnaire and Preparation Analysis:

A questionnaire survey was conducted mainly with residents, students and educators in the three cities that were subjected to research main study topic. The questionnaire survey was therefore addressed to different people living in different environments. Therefore to achieve the main objective of the field survey and to identify the most important issues and problem areas related to human health, the design of the questionnaire forms and type of questions addressed have been determined according to the nature of building type that was supposed to be covered. This section (4.5) discusses the design of the questionnaire form and describes the appropriate techniques for selecting the questionnaire sample and determining the sample size.

4.5.1 The Questionnaire Design:

Due to the limitations in the available data in many areas in the country, the questionnaire survey was the most important technique for collecting data and information. The design of the questionnaire survey was based on four steps. These steps were: the selection of question areas, the construction of the questions, and the evaluation of the questions and the layout of the questionnaire (Marsh, 1982 And De Vaus, 1990). To select the question areas, it was important to anticipate what questions would ensure that relevant answers would be given. To work out which questions were needed, a number of aspects were identified. The most important were:

1. The problem areas, which determined the subjects to be evaluated.
2. Clarifying the subjects about which questions should be asked.
3. The method of evaluation and analysis selected
4. The technique to be used to carry out the questionnaire (the personal interview).

The second step of the questionnaire development was to select the type of questions needed. Two types were identified: closed or forced choice questions; and open-ended questions.

Open-ended questions give the respondents the chance to formulate their own answers. According to the question areas, the questionnaire design based mainly upon the forced choice questions. The main advantages of using this type of question were; to minimize the survey time, ease of coding, and they don't discriminate against the less talkative and inarticulate respondents. Attention was given to developing appropriate alternative responses, and a thorough range of responses was listed to avoid any misunderstanding. This was done by careful pilot testing using less structured approaches to locate the range of suitable responses (including " other" category) and by using the category (if other please specify) in many cases to allow for unanticipated responses. In some cases, however, open-ended questions were carefully used where needed to formulate people's opinions in regard to the specific topics of diseases and symptoms. This type of question had to be explained by the author (surveyor) to many of the respondents, once the initial questions were formulated, and before including them in the final questionnaire, the third step (evaluating questions) was progressed. As fowler (1984) suggests these initial questions were put in a trial sample for pilot testing. During this testing, a number of checks were carried out. These included; checking the ability of the item to discriminate, checking whether items formed the required scale, checking the reliability and validity of items and checking for response as required. To combine the final questions into the questionnaire (the final step), attention was given to the following points:

1. Answering procedures: with closed questions, for instance people were asked to tick appropriate boxes. On the other hand, with open-ended questions, a sufficient answer space was given.
2. Instructions: two types of instructions were used, general instructions and section inductions. General instructions included an introduction and the aim of the questionnaire, how the respondent was chosen, and the time required for interview. Since the questionnaire was divided into subsections a brief introduction was given in front of each section to help respondents get through it with more ease and without confusion.
3. Order of questions: a logical flow of questions was considered in the designing the questionnaire form. For instance, it started with easy questions about age, sex, occupation, and level of education. Where as open-ended questions were kept at a minimum level and placed only were possible and really needed mainly towards the end of the questionnaire.
4. Setting up for coding: with closed end questions specific codes were allocated to every response in it. This helped the data analysis phase (see section 4.5.6).

The questionnaire was designed to be addressed to two types of building users: educational and low-cost residential buildings. This differentiation in building use between private and public buildings led to a specific form of questionnaire design incorporating the following topics (see appendix 2):

1. The characteristics of the respondent, such as age, sex, education level, and occupation and any present diseases either inherited or affected after birth.
2. People's reactions to and their opinion on what finishing paint type they required and why that is so including brand type and favorite color.
3. People stated their natural reactions to specific paint types and how they saw they affected their personal health and welfare.

4.5.2 The Sampling Technique:

"... Sampling can provide an efficient and accurate way of obtaining information about a large number of cases. Just how efficient and accurate depends on the type of sample used, the size of sample, and the method of collecting data for the sample." (De Vaus, 1990).

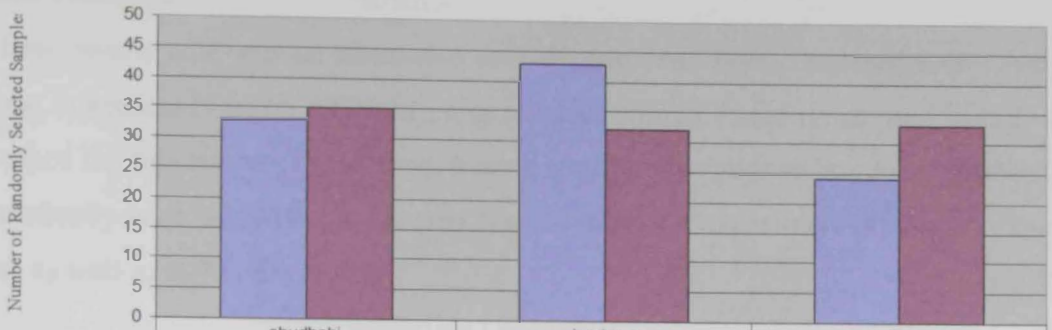
There are two types of samples: probability and non-probability (Smith, 1975; Fowler, 1984; And De Vaus, 1990). The probability sample is a technique in which each person in the population has an equal chance (probability) of being selected to be a representative sample. Where as in the non-probability sample, some people have a greater chance than others. Because of the nature of the research and importance of getting a wide and certain response from a certain group of the population the probability sample technique was selected. This technique was based on principle of random selection of selected building type users; that was to provide an equal chance of selection, to produce a representative sample and to increase the level of accuracy. This technique can be summarized in three main steps:

- Obtaining a complete sampling frame with a unique number for each building type.
- Determining the required sample size as described in the following section.
- The systematic sample can be simply obtained by working out the sampling fraction by dividing the total number of respondents, for instance by the required sample size.

4.5.3 The Sample Size:

The size of the required sample was chosen with consideration of total population size in each city (Abu Dhabi, Baniyas, and Shahama) the nature of present diseases and symptoms. The sample size was selected to cover the variety of ages dealing with such building types and characteristics anticipated and to provide a representative proportion of the number of building users in each selected building type (Figure 4.1).

Figure 4.1 Residential and Educational Samples In Emirate Of Abu Dhabi



4.5.4 Questionnaire:

The designed questionairre for this research study was designed academic use only and had no intention to intrude or effect any paint manufacturer or company of any kind. The main aim of this questionnaire is:

- To create awareness for environmental impacts of paints and coatings on the health of human beings in hot arid climates with respect to different weather conditions in the same region.
- To relate impacts concluded from questionnaire to paint types and function
- To analyze information from end users to find out the most suitable paint type for U.A.E environment

It is also important to understand that any results obtained from the analysis of these questionairres is not acurate or precise figures because they were tken randomly and on two age groups (10-30 years and 31-60 years of age) in the educational and residential. therefore results cant be applied on every space environment due to varios factors that play roles in effects on human health and space comfort. The questionairre form, as a sample is attached in appendix 5.

The quesionairre was basically designed to cover three parts: general information of randomly selected sample user, location and type of building type in question, symptoms and diseases related to building users before and after a paint job is completed, economic aspects as well as material knowledge available and present to all users.

4.5.5 Bar Chart Analysis Discussions

The following sections will explain the analysed rsults and conclusions that have been obtained from distributed survey questionnaires in two types of government executed buildings. Only two samples were chosen to cover the study in order to cover as much as possible as well as within the time period available to study the effect of paints on human health in the UAE in

general specifically in the emirate of Abu-Dhabi by covering it is three main cities with biggest populations: Abu Dhabi, Baniyas, shahama.

These results will later be taken into consideration and later compared with experimental results done in section (4.6) on different paint samples similar to the types used in both selected building types for this study. These experiments are done in order to build our conclusion on a well scientifically base study that is covered literate rally and experimentally by lab experiments and results as well as field case studies.

4.5.6 Interpretation And Information Analysis:

For many reasons, some representatives selected in the sample may not finally be included. The reason is that some might refuse, while others won't give required answers do to lack of understanding, too young in age to get a useful answer from them to any question, while others lack in seriousness of the study. To avoid such difficulties, these problems have been tackled in different ways. The first was by using techniques designed to reduce non-response by paying attention to methods of collecting data, using interpretation, or selecting other respondents (users) within the building. The second technique was the assumption of a larger sample size than should have been expected to remain in the end. Even when using good techniques in data collecting, the surveyor will still get around 20% non-responses in most cases (fowler, 1984).

The aim of this section is to describe the methods and techniques that were used for evaluating and analyzing collected data in order to identify the main issues and problem areas for which appropriate improvements will be recommended.

Once the data and information required for thesis study was collected, they had to be analyzed in order to achieve the objectives of the survey. To do so, suitable methods had to be used for the analysis, with respect to three factors that needed to be identified. These factors according to (De Vaus (1990) are number of variables being examined, the level of the measurement of these variables, and whether these data were used for descriptive or inferential purposes. On the basis of data variation, a bivariate technique was selected to deal with two variables simultaneously within reasonable range. The key factor in selecting the technique was the level of measurement variables, which was determined by the nature of the variable, how the question was asked, how it was coded and how the variables related to one another in case study.

Based on the technique demonstrated in figure (4.2) and in relation with the nature of the research case problem, Bivariate analysis[1], that was suggested by de Vaus (1990) and others, as an appropriate method for analysis for such circumstances, was selected for use in this study.

[1] The other two techniques of analysis (Univariate and multivariate), as shown in figure 4.2, are used to describe one characteristic of the sample and three or more at a time respectively.

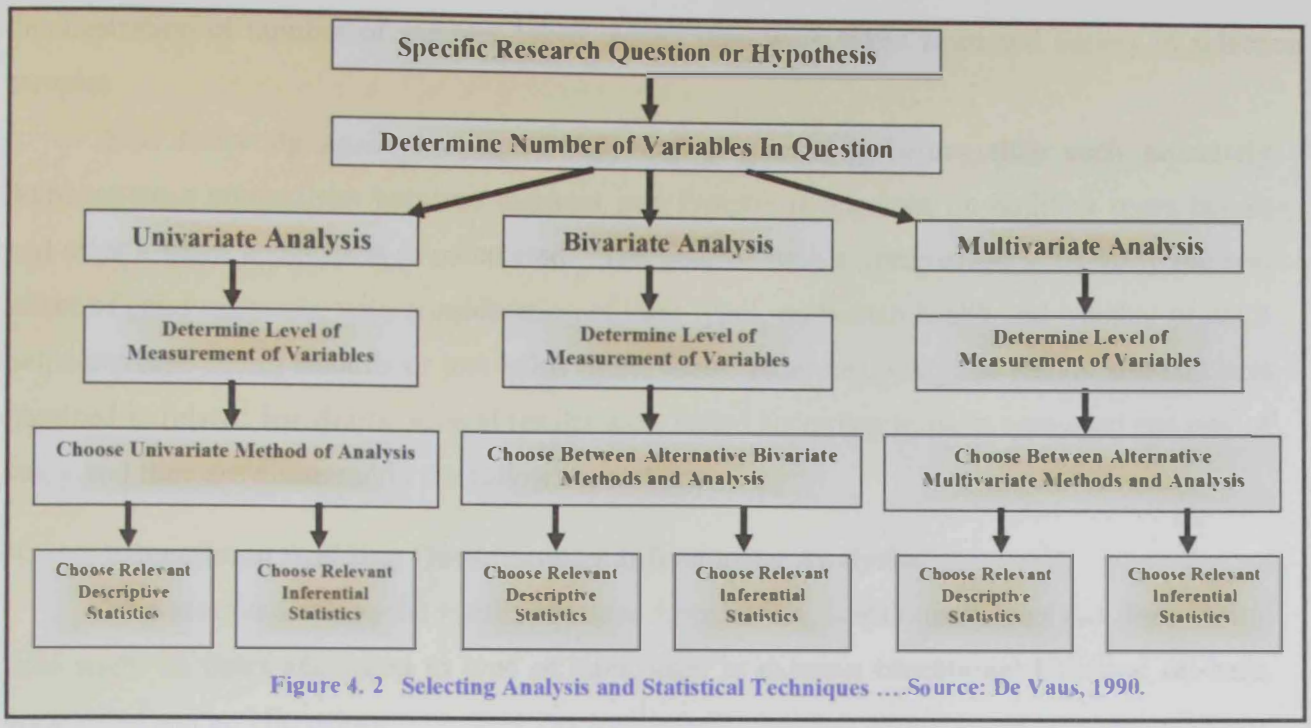


Figure 4. 2 Selecting Analysis and Statistical Techniques ....Source: De Vaus, 1990.

The main idea of this method is to look for relationships between two variables simultaneously and determine whether or not these variables are related (associated), using cross-tabulation. To conduct analysis, it was essential to choose a suitable statistical method. Because of the number of variables, the selected methods of the study analysis, and level of accuracy in variables, the choice of statistical method (using excel software[2]) was made through using two basic types of statistic methods: description and inferential analysis. Descriptive statistics are those, which produced summarized patterns of the responses of the respondents or interviewers. While the function of inferential statistics is too see if the patterns of the sample are likely to apply to the whole sample size. These methods of analysis, discussed above, were used to work out whether the two variables were associated.

The (Figure 4.3) and (Figure 4.4) distribute information related to different building finishing paints and their hazardous effects on users of both residential and educational buildings within the cities of case study: Abu Dhabi, Baniyas and Shahama. All samples have been taken randomly on various age and sex groups of both students and educators in educational buildings.

Although some of the gathered information hasn't been used in this study in direct way but if any further or more advanced studies are to be carried out in the future they might become very effective and very handy. But in this study they have only been used for the purpose of:

[2] Excel Microsoft software was selected to conduct the necessary analysis for such data because of many reasons (LUCL, 1988). The most important of which are:

1. It provides facilities range for the manipulation and analysis of both numeric and character data using a variety of techniques.
2. The statistical facilities range from the production frequency tables and bar charts to multivariate regression and analysis of variance.
3. It can also produce high quality graphical output.

demonstration of number of samples taken, where they were taken from and variety in selection of samples.

Still Referring again to (Figure 4.3) and (Figure 4.4) below, they each separately demonstrate a comparison between diseases and symptoms apparent on building users before and after a paint application is completed. The goal of such a comparison is to study the real effect of paint materials, with consideration of their types, on human health and whether or not it helps increase health hazards or just helps ignite them. After analyzing the results and numbers obtained in related bar charts; several results were stated according to paint type used and city of study and they are discussed in the following sections.

A. Educational Building Questionnaire Information Analysis:

This section displays the results obtained from survey questionnaire analysis done during case study on users according to type of paint used in existing educational building: oil-base, water base and acrylic paints.

A1. Oil Base Paints:

- Over 50% of building users are subject to suffer: breathing difficulties, discomfort, and runny nose and in some cases coughing spells. Oil base paints emit components or fumes that irritate the respiratory system and mucous membranes and tissues.
- There is a 70% increase in victims suffering from Respiratory diseases and symptoms in Shahama city , it followed by a 50% increase in effected victims in Baniyas; while it is less effective on building users in Abu Dhabi
- There are a high number of complaints from users suffering: dizziness, nausea, headaches. This indicates that oil pints are most likely to emit fumes and gases related to irritating nervous system organs , tissues and membranes

  Highest obtained hazardous results were found in Shahama, Baniyas and then Abu Dhabi

A2. Water Base Paints:

- Nausea, dizziness and headaches were highly reported in several people of case study, but were the highest in city of Abu Dhabi. There was a range of 40% building users who complained from being nausea which is considered a moderately high number. This in it is turn indicates the presence of components, fumes or gases that irritate the nervous system cells creating a sense of discomfort that appears in form of nausea, dizziness and headaches in most cases
- In comparison very little complaints of eye irritation and respiratory problems were obtained. Those that were filed of people who already suffering from these symptoms

even before the paint job was done; therefore it may not be due to paint material which used to be suspected before study was carried out.

- Highest obtained hazardous results were found in Abu Dhabi, Baniyas and then Shahama.

A3. Acrylic Base Paints:

- Irritation of eyes and tearing was highest complaint obtained from the study of acrylic paints.
- It was noticed that it was basically associated with building users already complaining and suffering of irritant eyes even before paint jobs were done; therefore it may not be due to paint material which used to be suspected before study was carried out

  Highest hazardous effect was found in Baniyas followed by Abu Dhabi and finally Shahama.

A4. General Comments:

- Nervous system diseases and symptoms in form of headaches, dizziness and nausea were highest results obtained in case study
- Respiratory diseases and symptoms were mainly associated with building users of oil base painted spaces.
- Cases study analysis on different paint types in case study showed different results in numbers and diseases. Therefore this is evidence that there are other factors playing a role in apparent study and not just the components of any type of paint material.
- Study analysis on educational buildings shows that it is advised to use:
  - Acrylic based paints in coastal and semi coastal regions (ex: Abu Dhabi & Shahama).
  - Water base paints are suggested to be used in desert regions such as in Baniyas.

- study analysis shows that it is not advised to use:
  - water base paints in coastal regions (ex. Abu Dhabi)
  - oil base paint in semi coastal desert regions (ex. Baniyas and Shahama)

It is important to note that paint wasn't the only factor helping in rise of effected victims even if it is one of the main factors.

B. Residential Building Questionnaire Information Analysis:

This section displays the results obtained from survey questionnaire analysis done during case study on users according to type of paint used in existing residential building: oil-base, water base and acrylic paints.

B1. Oil Base Paints:

- Tearful eyes, burning feeling and redness are the highest symptoms registered for building users in case study. A large increase in victims to eye irritation reaches 60% in Baniyas and 50% in both Abu Dhabi and Shahama city. This indicates the presence of eye irritant components, gases or fumes released from the paint material.
- Nausea, dizziness and headaches were highly reported in case study of case study, but was the highest in the city of Abu Dhabi. There was a range of 20% users who complained from being headaches which is considered a moderately high number. This in it is turn indicates the presence of components, fumes or gases that irritate the nervous system cells creating a sense of discomfort that appears in form of nausea, dizziness and headaches in most cases
- There is a range of 20% in victims suffering from Respiratory diseases and symptoms in Shahama city, while it is less effective on building users in Abu Dhabi and Baniyas. These hazardous effects on respiratory system are in the form of: coughing, breathing difficulties and uncomfort and runny noses. These diseases and symptoms are the evidence of presence of paint components, fumes or gases that irritate the respiratory system and lungs in hazardous way. Highest Obtained hazardous results were found in Baniyas followed by Abu Dhabi and Shahama city

B2. Water Base Paints:

- Irritation of eyes and tearing was highest complaint obtained from the study of water base paints which reached more than 32% in Baniyas and other two cities.
- There is a 50% increase in subjected victims suffering from Respiratory diseases and symptoms in case study of case study. These hazardous effects on respiratory system are in the form of: coughing, breathing difficulties and uncomfort and runny noses. These diseases and symptoms are the evidence of presence of paint components, fumes or gases that irritate the respiratory system and lungs in hazardous way
- Nausea, dizziness and headaches were highly reported in case study of case study, but was considerably low and hardly noticed at all.

  Obtained hazardous results were found in Baniyas followed by Abu Dhabi and then Shahama.

B3. Acrylic Base Paints:

- Nausea, dizziness and headaches were highly reported in case study of case study, but was the highest in the city of Abu Dhabi. There was a range of 10% users who complained from being headaches which is considered a moderately high number. This

in it is turn indicates the presence of components, fumes or gases that irritate the nervous system cells creating a sense of discomfort that appears in form of nausea, dizziness and headaches in most cases

- There is a 50% increase in subjected victims suffering from Respiratory diseases and symptoms in case study of case study. These hazardous effects on respiratory system are in the form of: coughing, breathing difficulties and uncomfort and runny noses. These diseases and symptoms are the evidence of presence of paint components, fumes or gases that irritate the respiratory system and lungs in hazardous way
- Tearful eyes, burning feeling and redness are the highest symptoms registered for building users in case study. A large increase in victims to eye irritation reaches about 50% in case study of the study. This indicates the presence of eye irritant components, gases or fumes released from the paint material.
- Vomit is associated with the use of acrylic paints only in case study. Indicating the ingestion of components or fumes that irritate the digestive system and may cause stomach upsets.

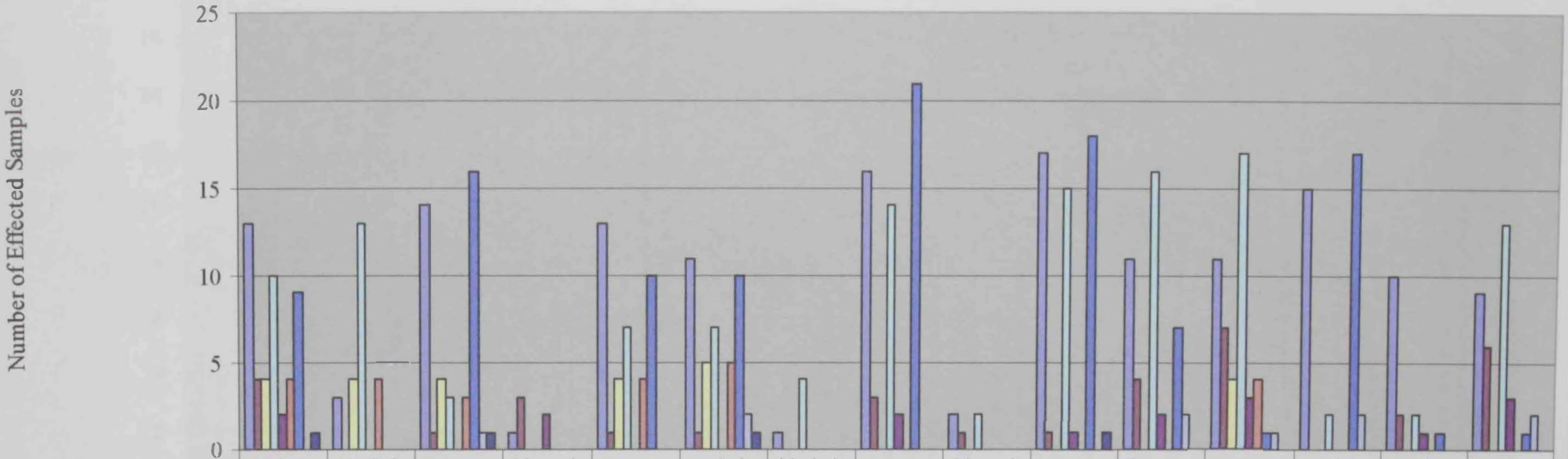
Obtained hazardous results were found in Shahama followed by Abu Dhabi and then Baniyas.

B4. General Comments:

- Eye irritation, burning feeling, redness and tears were highest results obtained in case study of the case study
- Paint knowledge and information literature was very vague and hardly many knew a lot about the material or components that it was based on.
- Vomiting was mainly associated with building users of acrylic painted spaces in case study of the case study
- Cases study analysis on different paint types in case study showed different results in numbers and diseases. Therefore this is evidence that there are other factors playing a role in apparent study and not just the components of any type of paint material.
- Study analysis on residential buildings shows that it is advised to use:
    - Water Base Paints In semi coastal regions (ex: Shahama)
    - Acrylic Paint is suggested for coastal and desert regions (ex: Abu Dhabi and Baniyas).
- study analysis shows that it is not advised to use:
    - water base paints in coastal and desert regions (Abu Dhabi and Baniyas)
    - oil paint in semi coastal regions are not advised (ex Shahama)

It is important to note that paint wasn't the only factor helping in rise of effected victims even if it's one of the main factors.

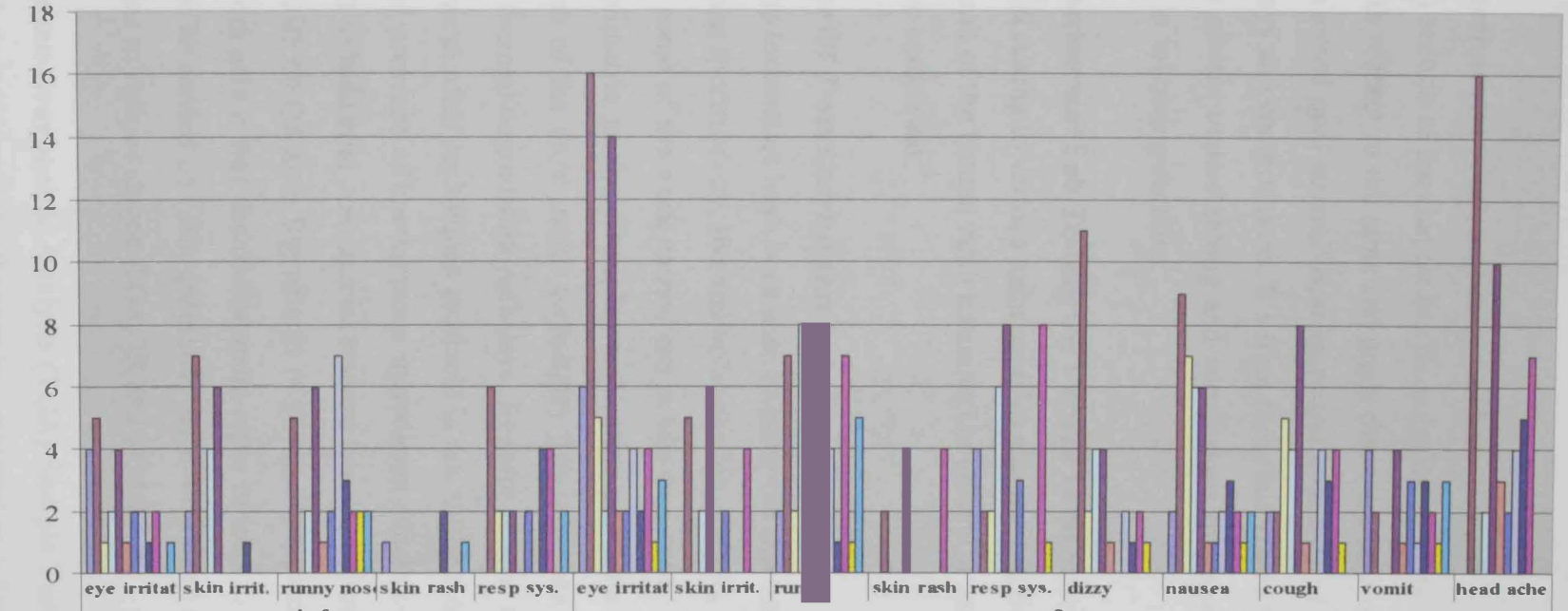
FIGURE 4.3 Symptoms and Diseases Comparison Chart Before & After Paint Application- Educational Buildings-Emirate of AbuDhabi



	eye irritat	skin irrit.	runny nos	skin rash	resp sys.	eye irritat	skin irrit.	runny	skin rash	resp sys.	dizzy	nausea	cough	vomit	head ache
abudhabi oil base	13	3	14	1	13	11	1	16	2	17	11	11	15	10	9
abudhabi water base	4	0	1	3	1	1	0	3	1	1	4	7	0	2	6
abudhabi acrylic	4	4	4	0	4	5	0	0	0	0	0	4	0	0	0
baniyas oil base	10	13	3	0	7	7	4	14	2	15	16	17	2	2	13
baniyas water base	2	0	0	2	0	0	0	2	0	1	2	3	0	1	3
baniyas acrylic	4	4	3	0	4	5	0	0	0	0	0	4	0	0	0
shahama oil base	9	0	16	0	10	10	0	21	0	18	7	1	17	1	1
shahama water base	0	0	1	0	0	2	0	0	0	0	2	1	2	0	2
shahama acrylic	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0

Diseases & Symptoms

FIGURE 4.4 Symptoms and Diseases Comparison Chart Before & After Paint Application- Residential Buildings-Emirate of AbuDhabi



	eye irritat	skin irrit.	runny nos	skin rash	resp sys.	eye irritat	skin irrit.	rur	skin rash	resp sys.	dizzy	nausea	cough	vomit	head ache
	before					after									
oil abudhabi	4	2	0	1	0	6	0	2	0	4	0	2	2	4	0
oil baniyas	5	7	5	0	6	16	5	7	2	2	11	9	2	2	16
oil shahama	1	0	0	0	2	5	0	2	0	2	2	7	5	0	0
water abudhabi	2	4	2	0	2	2	2	8	0	6	4	6	4	0	2
water baniyas	4	6	6	0	2	14	6	6	4	8	4	6	8	4	10
water shahama	1	0	1	0	0	2	0	3	0	0	1	1	1	1	3
acrylic abudhabi	2	0	2	0	2	2	2	0	0	3	0	1	0	3	2
acrylic baniyas	2	0	7	0	0	4	0	4	0	0	2	2	4	1	4
acrylic shahama	1	1	3	2	4	2	0	1	0	0	1	3	3	3	5
wallpaper abudhabi	2	0	2	0	4	4	4	7	4	8	2	2	4	2	7
wallpaper baniyas	0	0	2	0	0	1	0	1	0	1	1	1	1	1	0
wallpaper shahama	1	0	2	1	2	3	0	5	0	0	0	2	0	3	0

Diseases & Symptoms

Figure 4.4 Finishing Materials & Their Effect on Increasing Symptoms & Diseases - Residential Buildings- Emirate of Abu Dhabi

4.6 Experimental Work and data Analysis

This section of the chapter has been dedicated to the study of experimental work and data analysis with respect to the aims and goals that were intended at beginning of our research. To achieve the aimed goal several techniques and hundreds of samples were prepared and tested in different ways and compositions. It's from these laboratory tests that many results were achieved and lead to certain understanding and conclusions that shall be discussed in further detail and description in following sections.

4.6.1 Experimental Lab Testing On Various Paint Samples:

Experimental testing to various paint samples was done in the laboratory of CLU (central laboratory unit of the United Arab Emirates University in Alain city and tests took around six months to be completed.

4.6.2 Type Of Tests Carried Out In Laboratory:

Many techniques have been used to study the thermal degradation of polymers, including pyrolisis mass spectroscopy, thermal volatilization analysis, thermo gravimetric analysis, etc. in this study , some of the work carried out in this study over the past few months was done using thermo gravimetric analysis couples to Fourier transform infrared spectroscopy (TGA/FTIR) which is one of the most useful techniques that scientists have at their disposal to probe and understand thermal degradation pathways. Reasons related to why this technique was used from between several other techniques available is due to the fact that paint samples used during this study lacked presence of known exact ingredients and amount of compositions in each of them with respect to industrial commercial reasons which implies necessity of secrecy. From here the need to inquire on the main ingredients of which these paints were made from was difficult and therefore from here it was decided on main types of tests to be run and then decide on how other tests were to be carried on. But generally, there were three major experimental tests done on the paint samples in various stages: TGA, IR and TGA/FTIR.

A. Thermo Gravimetric Analysis (TGA) Sample Tests:

TGA measures weight changes in a material as a function of temperature (or time) under a controlled atmosphere. It is principal uses include measurement of a material's thermal stability and composition. TGA instruments are routinely used in all phases of research, quality control and production operations.

An atmospheric TGA is a highly sensitive electronic balance (+/- 0.0001 g) housed in a sealed, heated, quartz reaction chamber. The TGA technique takes only milligrams of material to measure weight loss or gain as materials are heated in an inert atmosphere (to prevent Oxidative decomposition as in burning). The atmospheric TGA can characterize the thermal and oxidative stability of organic and inorganic materials, the extent and kinetics of gas-solid reactions, the composition of multi component systems, moisture and volatiles content, and decomposition kinetics. Thermo gravimetric Analysis is a technique in which in the mass of a substance is measured as a function of time or temperature while the substance is subjected to a controlled temperature program. The results obtained from this technique are represented with the aid of a TG Curve[3].

Figure 4. 5
TGA Device

Change of sample weight is caused by formation or destruction of physical or chemical bonds during increase of temperature. Namely, from this process, samples release volatiles or produce reactants to cause change of sample weight. From Thermogram curve, we found out the temperature when sample weight was decreased, and distinguished different materials.

1. The temperature-weight change curve will be obtained by TGA
2. The curve can be possible the qualitative (ex. Thermal stability, thermal properties, pyrolisis) or quantitative [composition ratio within a material, mass of ash, mass decrease within a constant temperature (or time) range] analysis for samples
3. Can be calculated velocity variables from results obtained in the broad temperature
4. Temperature range of TGA.

A.1. Advantages and Disadvantages of TGA

- ***Advantages***:

TGA provides a rapid means to distinguish one polymer from another on the basis of the temperature range, extent, rate, and activation energy of decomposition

- ***Disadvantages***:

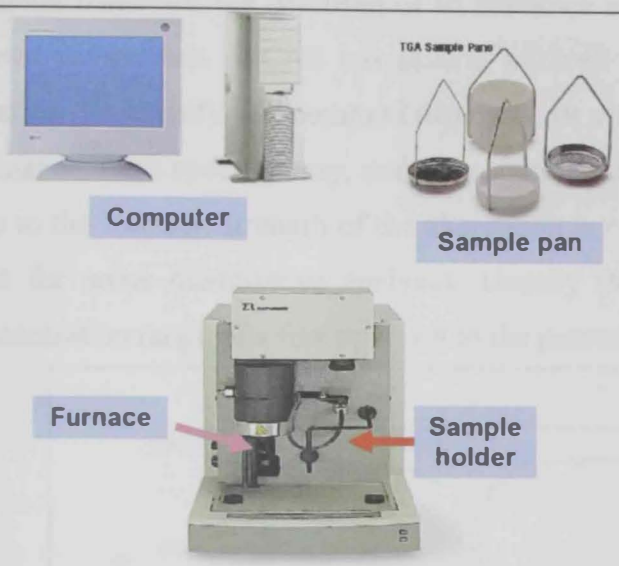
Many polymers do not show large enough decomposition differences to provide adequate resolution. Also, the thermal stability of a polymer can be affected by additives, previous heat treatment, and the inclusion of other substances. For an unknown sample, it is very difficult to identify the materials.

[3] Thermogram (TG curve): curve of weight or percent weight versus a function of time or temperature. It shows compounds or properties of products resulting from physical changes or chemical reaction in specific temperature range – associated with changes of molecular structure.

A.2. Advanced Techniques of TGA

TGA technique can be applied to most materials that degrade due to instability brought on by increased temperature. However, there are limitations to applying this technique to unknown materials. Some interesting developments: Combination TGA with Mass spectroscopy, Fourier transforms infrared. These combinatory techniques have expanded to identify of unknown materials.

A.3 Instruments:



- Thermo gravimetric Analyzer
- high sensitive thermo balance
- sample pan (put samples)
- furnace (heating rate : max 200℃/min)
- thermostat and thermo sensor (Increase heat at constant rate and maintenance of constant temp.)
- recorder (data record)
- gas injector (inactive gas N_2 or Ar)
- computer (process and analysis of data)

Figure 4. 6 Parts of TGA Device

B. Infra Red (IR) Sample Tests:

Fourier Transform Infrared Spectroscopy (FTIR) is a powerful tool for identifying types of chemical bonds in a molecule by producing an infrared absorption spectrum that is like a molecular "fingerprint". FTIR is most useful for identifying chemicals that are either organic or inorganic. It can be utilized to quantitate some components of an unknown mixture. It can be applied to the analysis of solids, liquids, and gasses. This analyzing technique (FTIR) can be used to identify chemicals from spills, paints, polymers, coatings, drugs, and contaminants. FTIR is perhaps the most powerful tool for identifying types of chemical bonds (functional groups). The wavelength of light absorbed is characteristic of the chemical bond as can be seen in this annotated spectrum.

B.1. FTIR Absorption Spectrum Interpretation:

By interpreting the infrared absorption spectrum, the chemical bonds in a molecule can be determined. FTIR spectra of pure compounds are generally so unique that they are like a molecular "fingerprint". While organic compounds have very rich, detailed spectra, inorganic compounds are usually much simpler. For most common materials, the spectrum of an unknown can be identified by Comparison to a library of known materials; the spectrum of an unknown

can be identified by comparison to a library of known compounds. WCAS has several infrared spectral libraries including on-line computer libraries. To identify less common materials, IR will need to be combined with nuclear magnetic resonance, mass spectrometry, emission spectroscopy, X-ray diffraction, and/or other techniques by interpreting the infrared absorption spectrum, the chemical bonds in a molecule can be determined. FTIR spectra of pure compounds are generally so unique that they are like a molecular "fingerprint". While organic compounds have very rich, detailed spectra, inorganic compounds are usually much simpler. For most common materials, the spectrum of an unknown can be identified by comparison to a library of known compounds. WCAS has several infrared spectral libraries including on-line computer libraries. To identify less common materials, IR will need to be combined with nuclear magnetic resonance, mass spectrometry, emission spectroscopy, X-ray diffraction, and/or other techniques. Due to the fact that strength of the absorption is proportional to the concentration, FTIR can be used for some quantitative analyses. Usually these are rather simple types of tests in the concentration range of a few ppms up to the percent level.

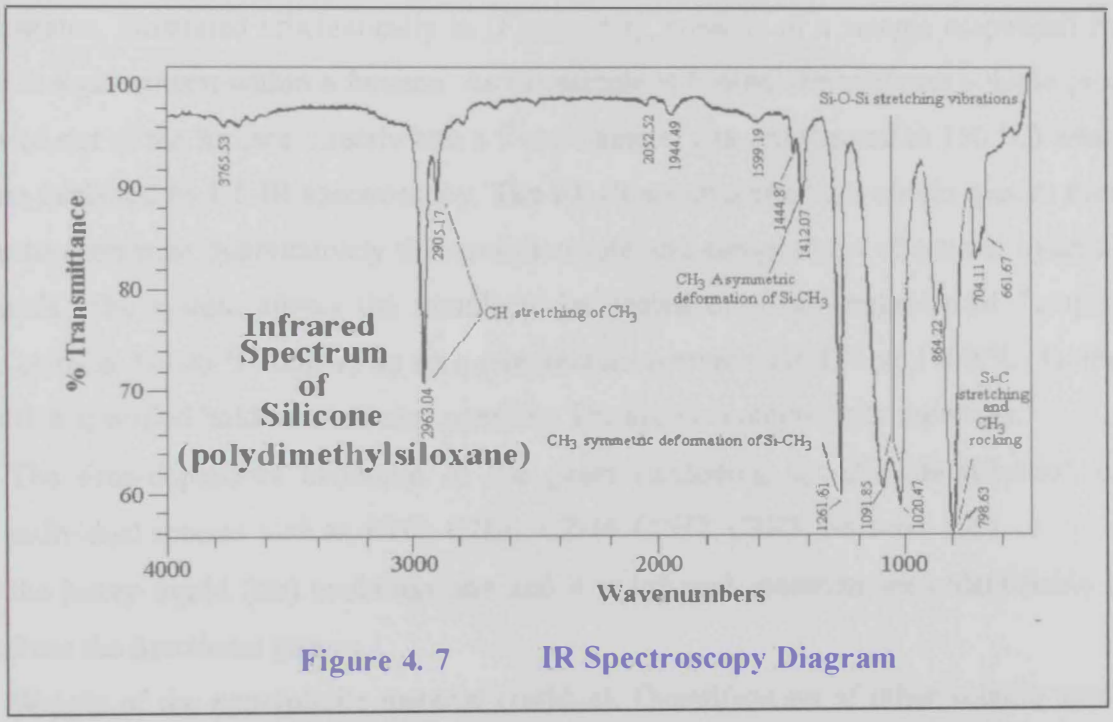


Figure 4. 7 IR Spectroscopy Diagram

B.2. Sample Preparation:

Samples for FTIR can be prepared in a number of ways. For liquid samples, the easiest is to place one drop of sample between two plates of sodium chloride (salt). Salt is transparent to infrared light. The drop forms a thin film between the plates. Solid samples can be milled with potassium bromide (KBr) to form a very fine powder. This powder is then compressed into a thin pellet which can be analyzed. KBr is also transparent in the IR. Alternatively, solid samples can be dissolved in a solvent such as methylene chloride, and the solution placed onto a single salt plate. The solvent is then evaporated off, leaving a thin film of the original material on the plate.

This is called a cast film, and is frequently used for polymer identification. Solutions can also be analyzed in a liquid cell. This is a small container made from NaCl (or other IR-transparent material) which can be filled with liquid. This creates a longer path length for the sample, which leads to increased sensitivity.

C. Thermo-Gravimetric Analysis Couples To Fourier Transform Infrared Spectroscopy (TGA/FTIR) Sample Tests:

The combination of TGA/FTIR provides a very useful tool for the determination of the degradation pathway of polymers, copolymers or the combination of one of these with additives. But still unfortunately TGA/FTIR does not provide answers for all problems but still it is one of the most useful techniques and was of great aid to our study.

C.1. Instruments:

The TG-FTIR instrument consists of a thermo-gravimetric analyzer (TG) coupled with a Fourier-Transform Infrared (FTIR) spectrometer for the analysis of evolved gases.

The apparatus, illustrated schematically in (Figure 4.8), consists of a sample suspended from a balance in a gas stream within a furnace. As the sample is heated, the evolving volatile products are carried out of the furnace directly into a 5 cm diameter gas cell (heated to 150 °C) where the gases are analyzed by FT-IR spectroscopy. The FT-IR spectrometer can obtain spectra every 40 seconds to determine quantitatively the evolution rate and composition of several hydrocarbon compounds. The system allows the sample to be heated on a pre-programmed Temperature profile, at rates 3–100 °C min-1, up to a temperature between 20 °C and 1100 °C. Isothermal steps with a specified hold time are also possible. The system continuously monitors:

- The time-dependent evolution of the gases (including specific identification of the individual species such as, CH4, C2H6, C2H4, C2H2, C3H8, benzene, etc.)
- the heavy liquid (tar) evolution rate and it is infrared spectrum with identifiable bands from the functional groups

Weight of the non-volatile material (residue). Quantification of other volatile species is also possible. An analysis of C, H, N, S and Cl in the residue at the end of the pyrolisis experiment can be obtained by introducing oxygen to burn the residue and analyzing the combustion products.

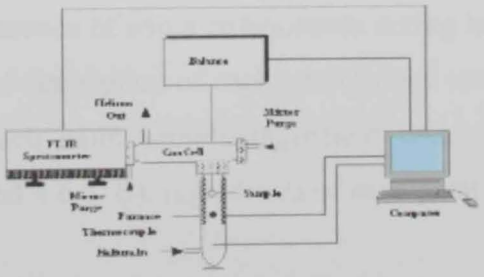


Figure 4.8. A Schematic Diagram of the TG-FTIR System

C.2. TGA-IR Interface Operation:

The TGA-IR interface combines the sample analysis tools of a TGA with the identification power of an FT-IR spectrometer. The TGA-IR Interface and software combines FT-IR with Thermo-gravimetric Analysis (TGA) to offer real-time monitoring of gases as they evolve from a sample. The combined system measures the change in weight of a sample as function of temperature or time in a controlled atmosphere and collects IR spectra of the evolved gas components.

The TGA-IR interface is connected to the TGA via a heated transfer line. As gases evolve during the TGA experiment, they pass into the flow cell of the TGA-IR interface where the infrared spectra are collected. The TGA-IR Interface is beneficial in determining sample characteristics such as decomposition pathways, thermal stability or sample integrity. It is flexible interface design can be placed in the sample compartment of the spectrometer. The TGA flow cell is compatible will all types of evolved gases and materials. Additionally, the large flow cell diameter provides high throughput and prevents spectral interference caused by deposit is on the walls. The TGA-IR Interface features a flow cell that is spring loaded and easily removed for cleaning.

4.6.3 Interpretation And Information Analysis Of Lab Test Results:

The TGA and FTIR experimental sample tests were applied on around 100 samples of pure and various composition samples for either water or oil base paints. The readings obtained from these samplings showed that though these paints had different trade names they were actually almost the same material and therefore when tested under the same accelerated increasing time periods and temperature they would release almost the same components. This could only mean that they are all the same and the change in the trade mark is for commercial reasons or to provide certain required properties needed for design or climate purposes therefore required different method of mixing. But whether so, the fact still remains that they are almost all the same material. From here came the need to reduce the sampling list into a short list from which a more detailed study was made using TGA/FTIR experimental tests where concentrated on six paint samples (three water base paints and three oil base paints) which were used as a reference for all other samples.

Due to the repetitive appearance of some components during laboratory sample testing it was considered best to give a brief description of each one of them including health hazard data. A more clear composition of each paint sample ingredient content will later be discussed separately in sections (4.6.3. A. and 4.6.3. B), ingredients of each paint sample will be mentioned clearly.

- ***Water:***

It is well known that water is not hazardous in any of it is material forms (solid, liquid or gas state). Therefore it has no potential effect on human health.

- ***Carbon Dioxide:***

According to several references, Carbon dioxide is an inorganic compound with dangerous health effects. Excessive inhalation of vapors can be harmful and may cause headache, dizziness, asphyxia, anesthetic effects and possible unconsciousness as well as, shortness of breath, and Nausea and drowsiness. It is important to know that CO_2 vapor is very dangerous and harmful or can be fatal if swallowed. Carbon dioxide Vapors and liquids are considered Irritating to eyes, skin, mucous membranes, and respiratory tract. Ingestion of this gas can cause possible chemical pneumonitis if aspirated into lungs. As for Chronic Effects: (Effects due to excessive exposure to the raw materials of this mixture) May cause liver abnormalities, kidney, spleen, lung or brain damage, cardiac abnormalities.

- ***Acetic Acid (Ethanoic Acid):***

Ethanoic Acid is a stable material of a colorless appearance. When dealing with this component it is advised to avoid substances such as alcohols, aldehydes, halogen-halogen compounds, oxidizing agents, metals, alkali hydroxides, anhydrides, nonmetallic halides, permanganates, peroxides, and ethanolamine. This material is strongly corrosive and causes serious burns. This material is to be carefully dealt with because it may cause respiratory tract irritation, eye and skin irritation and it also has been found to cause digestive tract irritation with symptoms of severe pain, nausea, vomiting, diarrhea, and shock.

Ethanoic Acid hasn't been known to attack any specific targets organs. However, it may cause more than just causes severe eye irritation. Contact with liquid or vapor causes severe burns and possible irreversible eye damage. Contact of this material with skin Causes skin burns. If absorbed through skin ***Ethanoic Acid,*** maybe very harmful and cause skin blackening and hyperkeratosis of the skin of the hands. Ingestion of ***Ethanoic Acid*** should also be avoided because of recorded reports that state it to be a possible cause of severe and permanent damage to the digestive tract. It May also cause Polyuria, Oliguria and Anuria. Rapidly absorbed from the gastrointestinal tract. Inhalation of this acid, though can be delayed, causes chemical burns to the respiratory tract. But Exposure to this material may lead to bronchitis, Pharyngitis, and dental erosion. It is important to put in to consideration that Ethanoic acid May also is absorbed through the lungs.

- ***2-Ethyl-2-Hexenoic Acid***

2-Ethyl-2-Hexenoic Acid is a Colorless and transparent liquid with characteristic odor. It has a property of Minor solubility in cold water and alcohol. It becomes a solution when mixed in warm water and ethyl ether. Another of it is physical properties is that it possesses high purity, light color value and so on.

Possible Hazards related to this paint component is: it is Corrosive, Causes burns and is Harmful if taken in by inhalation, in contact with skin and if swallowed. Studies have shown that over exposure to this acid can Target Liver. It is really important to consider possibility of 2-Ethyl-2-Hexenoic Acid in causing damage to the child in the womb.

Oral dosing studies carried out by the US National Toxicology Program over two years on rat and mice showed an increase incidence of malignant tumors following administration of C12 and C23 Sulpho-chlorinated Paraffin's. This evidence indicates that the product is carcinogenic on animals when dosed orally at very high levels, thus stressing the need for care in handling and the need to minimize exposure from all routes to as low a level as is reasonably practicable.

- ***2-Methylnonane:*** *(No Data Found)*
- ***Isobutyl-Cyclohexane:***

Isobutyl-Cyclohexane is a colorless and volatile liquid with a slightly pungent odor resembling that of chloroform or benzene. Exposure to Cyclohexane can occur through inhalation, ingestion, and eye or skin contact. Cyclohexane is an irritant of the eyes and mucous membranes in humans. By analogy with the effects in animals, exposure to high concentrations is expected to cause narcosis. Exposure to 300 ppm caused irritation to the eyes and mucous membranes in workers. Exposure to higher concentrations is likely to cause dizziness, nausea, and other narcotic effects. On repeated contact, Cyclohexane is a defatting agent. Cyclohexane has not been shown to cause hematological changes associated with exposure to benzene. Exposure to high vapor concentrations causes convulsions, and ingestion of toxic doses causes diarrhea, circulatory collapse, and death. Chronic dermal contact may cause a dry, scaly, fissured dermatitis.

- ***2 Hexane (E) + (Z) (Hexahydrobenzene, Cyclohexane)***

This gas is described to be a clear colorless liquid with a petroleum-like odor. It is used in solvent for lacquers and resins, painter mediate and varnish remover, in the extraction of essential oils, in analytical chemical for molecular wt determination, in the

manufacture of Adipic acid, benzene, Cyclohexane, Cyclohexanol, Cyclohexyl Chloride, Nitrocyclohexane, Solid Fuel for camp stoves, in industrial re-crystallization of steroids, in fungicidal formulations- has slight fungicidal action.

(2) Hexane is Stable at room temperature in closed containers under normal storage and handling conditions. As for it is Hazardous Decomposition they are: Carbon monoxide, irritating and toxic fumes and gases, carbon dioxide. However, it is a Non-corrosive liquid. There are several exposure effects to ***(2) Hexane*** through different routes: Ingestion, Inhalation, absorbed by through skin, eye irritation.

Ingestion of large amounts of ***(2) Hexane*** may cause gastrointestinal irritation, liver and kidney damage or also cause central nervous system depression, characterized by excitement, followed by symptoms of: headache, dizziness, drowsiness, and nausea. Advanced stages may even cause collapse, unconsciousness, coma and possible death due to respiratory failure. Another effect to exposure of this gas can cause vascular collapse and damage. Aspiration of material into the lungs may cause chemical pneumonitis, which may be fatal. This material can be absorbed through skin in harmful amounts creating an irritation with burning pain, itching and redness. It is can cause mild eye irritation.

- ***Ammonia:***

Ammonia is a corrosive, colorless, gas with a sharp odor. Some liquids release ammonia gas. Ammonia is used to make household cleaners, refrigeration unit is, fertilizers, explosives, fuels and other chemicals. Humans and animals release ammonia in urine.

Ammonia is very alkaline and reacts corrosively with all body tissues. Inhalation of *Ammonia is* considered Corrosive and is extremely destructive to tissues of the mucous membranes and upper respiratory tract. Symptoms may include Burning Sensation, Coughing, Wheezing, Laryngitis, Shortness of Breath, Headache, Nausea and Vomiting. Inhalation may be fatal as a result of spasm inflammation and edema of the larynx and bronchi, chemical pneumonitis and pulmonary edema. Where as Ingestion should also be avoided due to the fact that it being Corrosive and Swallowing can cause severe burns of the mouth, throat, and stomach, leading to death. Symptoms of ammonia ingestion are Nausea sore throat, vomiting and diarrhea and which occur frequently following ingestion. Other symptoms due to ingestion are: Swelling of the lips, mouth, and larynx, and oral or esophageal burns may occur if concentrated ammonia solutions are ingested. Ammonia ingestion studies have reported that they May cause irritation, difficulty in breathing and kidney damage. Skin Contact with this alkaline corrosive substance may

produce pain, redness, severe irritation or full thickness burns. Related to dermal contact effects with ammonia is it may be absorbed through the skin with possible systemic effects. Still again Eye Contact with *Ammonia is* Corrosive causing blurred vision, redness, pain, severe tissue burns and eye damage. Eye exposure may result in temporary or permanent blindness. But then in general it can be stated that the Chronic Exposure to this poisonous substance Prolonged or repeated skin exposure may cause dermatitis or may even cause eye, liver, kidney, or lung damage.

- ***Nonylphenol:***

Nonylphenol gas is Viscous, colorless to straw colored liquid, with a mild phenolic odor. This gas can cause some very harmful affects due to absorption or inhalation when exposed to certain concentrations to it. The Acute Health Hazards caused by Inhalation of concentrated vapor may irritate the nose and throat. While Eye Contact has been known to cause severe eye burns. As for skin contact with this gas created skin burns. Another method of absorption of this harmful component is Ingestion which can be very Harmful if swallowed. ***Nonylphenol*** causes severe mucous membrane burns. The Chronic Health Hazards reported with exposure to this substance is basically based on prolonged contact with the skin causing sensitization but generally, No other chronic health hazard information is available.

- ***Propylbenzene:***

Propylbenzene is a Volatile organic compound of specific routes and effects of overexposure. For instance acute effect of eyes exposed to these substances might cause irritation. Dermal skin contact with Propylbenzene will cause irritation with prolonged or repeated contact. Absorption may occur through skin. Therefore, this material is to be avoided and minimized contact is to be obtained by maintaining high standards of industrial hygiene. Another route of exposure been stated by studies to be harmful if inhaled. Overexposure to high concentrations of vapor may cause respiratory tract irritation and may affect the brain or nervous system causing dizziness, headache, nausea or narcosis.

Propylbenzene has been reported to Contains more than 0.1% by weight of a material listed as a potential carcinogen. Other Chronic Effects that have been reported are a result of Prolonged or repeated overexposure may cause impaired lung function, blood disorders, liver and kidney damage.

- ***Hexyl Acetate:***

  Hexyl acetate is a moderate irritating substance which if inhaled will cause coughing and in some cases causing soar throat. As for this substances dermal effect on skin it will cause it to redden. If eyes are exposed to this component they will suffer of Redness. From this we find that this material is less effective then other paint components discussed in this section of chapter.

- ***Hexyl-Formate:***

  There have been no studies that prove that hexyl formate is a carcinogenicity material, but still any contact with skin or eyes may cause severe irritation or burns. Another method of overexposure to be avoided is Inhalation of vapors may cause severe irritation of the respiratory system. Inhalation of vapors may cause coughing, chest pains, nausea and vomiting. As for Ingestion, it may cause acute local tissue damage, with other effects ranging from nausea and dizziness to unconsciousness.

  Hexyl formate has been well known to target certain organs of the body which are: respiratory system, skin, kidneys, liver, and eyes. This paint component has a stable hazardous polymerization which will not occur. But there are certain restrictions to be taken into mind when dealing with this material such as avoiding heat, flame and other sources of ignition. Some of hexyl formate incompatibles are: strong oxidizing agents, strong bases, sulfuric acid.

- ***Methyl Mythacrylate (Methyl 2-Methyl Propenate)***

  Methyl acrylate is a clear, colorless, volatile liquid with a sweet but sharp fruity odor. Inhibitors, such as hydroquinone or it is methyl ether, are usually added to prevent spontaneous polymerization. This paint component is an irritant to the skin and High concentrations are extremely destructive to tissues of the mucous Membranes and upper respiratory tract, eyes and skin. Symptoms of exposure may include burning sensation, coughing, Wheezing, laryngitis, shortness of breath, headache, nausea and vomiting. It may also be the result in an allergic reaction. Studies have stated that Prolonged Exposure Can Cause: Lung irritation, chest pain and edema which may be fatal. Research has proven that target organs for this substance are: Respiratory system, eyes, skin.

  Meanwhile, there is inadequate evidence for the carcinogenicity of methyl acrylate in experimental animals. No human data were available and thus no evaluation of carcinogenicity in humans can be made. Whereas some of it is Hazardous combustion or decomposition products are toxic fumes of: Carbon monoxide, carbon dioxide.

A. Water Base Paints Samples:

A (TGA/FTIR) analysis was applied to three water base paint samples: Fenomastic silk 07, Jollyfix and Bengalac Gloss. These samples were taken as fresh samples from the manufacturers can. In all three samples water vapor was the first released component and each component released kept on increasing as temperature rates increased and time went by causing it is concentration also to increase till it reached it is peak and then fore started to decline once again and stating end of it is phase by the total burning of component and releasing carbon dioxide in it is place preparing for the start of a new gas phase and release of a new component as higher temperatures and time was applied.

A.1. Fenomastic Silk 07:

This paint sample released three main components according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made of: water, acetic acid (***Ethanoic Acid,***), and carbon dioxide.

A.2. Jollyfix:

This paint sample released three main components according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made of: water, 2-ethyl-2-hexenoic acid and carbon dioxide.

A.3. Bengalac Gloss

This paint sample released 1 main component according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made of: Water, 2-Methylnonane, Isobutyl-Cyclohexane-Trans, And Carbon Dioxide.

B. Oil base paint Samples:

A (TGA/FTIR) analysis was applied to three oil base paint samples: Pengaurd HB, jotacote and Durathane. These samples were taken as fresh samples from the manufacturers can and mixed according to appropriate standard portions stated in data sheets supplied from manufacturer manual.

In all three samples each component released kept on increasing as temperature rates increased and time went by causing it is concentration also to increase till it reached it is peak and then started to decline once again, stating end of it is phase by the total burning of component and releasing carbon dioxide in it is place preparing for the start of a new gas phase and release of a new component as higher temperatures and time was applied.

B.1. Pengaurd HB (Standard Composition 4A + 1B)

This paint sample released three main components according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made of : (2) Hexane (E) + (Z), ammonia and carbon dioxide.

B.2. Jotacote (Standard Composition 4A + 1B)

This paint sample released three main components according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made from: 2-Hexene (E) + (Z), Propylbenzene, Nonylphenol and Carbon Dioxide

B.3. Durathane (Standard Composition 9A + 1B)

This paint sample released three main components according to results obtained from TGA readings and with further inquiry and tests by TGA-FTIR analysis we found that this paint is basically made from: Hexyl Acetate, Hexylformate, Methyl Mythacrylate and carbon dioxide.

4.7 Summary:

The fieldwork covered two areas of concern: questionnaire design, distribution and information analysis and the second was the laboratory sample testing and result analysis. Two main sources were used; documentary resources and the fields survey. The survey was carried out by the author through three phases: observational survey, interviews with decision makers, authorities and users and through the conduction of an appropriate questionnaire design which was addressed to respondents of direct relation to the buildings subjected to case study topics.

On the basis of the research nature and importance of getting a concentrated response from direct users, the non-probability technique was adopted. This gave a certain group of the population a greater chance of being selected for the sample study. Once the data and information were collected, they were analyzed using Microsoft excel bar charts and power point demonstration slides. Despite some difficulties facing the author in conducting the fieldwork (see appendix 2), sufficient results were gained and have effectively been used effectively in the sequent stages of the study.

First part of the chapter brought us to the conclusion that there were different effects of paint materials on building users with consideration of building type. This was reflected very clearly in gathered questionnaire survey numeratic analysis which assumed that in case of educational building it is recommended to use: water base and acrylic paint in Shahama, oil base in Abu Dhabi and water base in Baniyas. Where as, in case of residential building it is recommended to use: acrylic paint in Baniyas, oil base in Baniyas and water base in Shahama. Further analysis to the reasons of such output results will be discussed in chapter 5 covering thesis study conclusion and recommendations.

As for second part of chapter covering experimental laboratory studies on around 100 paint samples which were carried out in CLU. From test samples done we were able to come out with an amazing result that though there are hundreds of paint trade markets available on the finishing material market and 10's of thousands of different paint types and colors available according to required design requirements and decorative purposes, but the fact remains that they are almost all the same material with different appearance. Deep studies into the components that build up these paints are the same even if they appear different. This enabled thesis study to be short listed to six main standard paint samples three water base paints (Jollyfix, Bengalac gloss and) and three oil base paint samples (Durathane, Pengaurd HB and Jotacote) several paint samples. These samples were further studied to try and diagnose the real components of which they were made. To do this A Thermo-Gravimetric Analysis Couples to Fourier Transform Infrared Spectroscopy (TGA/FTIR) was applied to each sample.

These particular analysis methods and techniques were chosen over other study techniques with relation to required specific components. These method of analysis express the absorption of specific wavelengths of infrared radiation is characteristic of chemical bonds, especially the bonds in organic compounds. Thus, the measurement of the infrared absorption spectra is a major tool in the characterization and identification of organic compounds. The (FTIR) refers to a fairly recent development in the manner in which the data is collected and converted from an interference pattern to a spectrum. Today's FTIR instruments are computerized which makes them faster and more sensitive than the older dispersive instruments. Thermo-gravimetric analysis coupled to Fourier transform infrared spectroscopy, TGA/FTIR, has been used to probe the degradation of several polymeric systems. The combination of TGA/FTIR spectroscopy provides a very useful tool for the determination of the degradation pathway of a polymer, copolymer or the combination of one of these with an additive. Since this technique only samples the gas phase (vapor phase), it is also important to analyze the solid residue at several temperature in order to ascertain the correlation between the evolved gases and rearrangements which occur in the solid which permit this evolution.

5.1 Introduction:

This chapter will be devoted to giving a brief summary of the whole thesis study including: literature and field work and experimental methodology. It will also demonstrate general conclusions reached from thesis study. These conclusions will be followed in (section 5.3) with recommendations of possible improvements that can be developed on paint materials with relativty to achieved results. Where as (section 5.4) will give advice and recommendation to users and authorities. Finally in suggestions for future research and development in the field of paint materials used for finishing and protective purposes will be covered in (section 5.5)

5.2 Summary And General Conclusions:

The thesis study consists of an introduction and 5 main chapters followed with several index rich with related data and results which will help reader in case of more desired understanding. These chapters in series with an order of common sense and ease of understanding to the benefit of readers, even to those whom hardly have any back ground on topic of the study.

A brief introduction to the study was given in Chapter 1 including a summary about the United Arab Emirates and the emirate of Abu Dhabi geography, related to study. Basically, the study covered paint finishing materials and their environmental impact on users within the building envelope of chosen samples. It was demonstrated in the form of diseases and systems apparent on them before and after paint application was done in any given space or building type in the Emirate of Abu Dhabi. However, to make the research more effective, a concentrated study was done on three particular chosen cities that are of the most populations. The aim and objectives of the study were discussed in (Section 1.2). Also in this chapter also discussed the literature methodology that was to be carried out through the study phase, hypothesis underlying the research and finally the structure of the research.

The comprehensive review of the literature (chapters two and three) focuses upon various building material classes, which divide materials into five main categories: metals, ceramics and glasses, composites, semiconductors ad polymer material. Examples of both natural and artificial building materials were given for each category except for semiconductors because they are basically related to the electronic industry. The following two chapters started the discussion on paints as being artificial man made finishing material that are non-constructive but used for protective and decorative purposes for various substrate material surfaces.

Chapter three is considered to be the main body of entire study that is why it was dedicated to the understanding of paint finishing main components, paint types and categories. second part of chapter (section 3.4) covered different methods of surface substrate with respect to type of original substrate material; due to importance of surface preparation which effected the

final result of a finished substrate surface and help prevent defects that not only effect the visual aspect of a finished surface but might also have effect on human health increasing allergies and diseases such as: rot, chalking, blistering etc. Then finally section 3.5 discussed health, safety and environmental aspects dealing with paint materials. This part discussed importance of labeling paint cans, first aid instructions and how to safely use paints. It also discussed protecting the environment by good formulation which is a major issue that will be given consideration in the recommendation for possible improvements.

In order to give thesis study stronger based ground from reality with respect to the obtained and gathered data from information and literature resources Field work and experimental methodology was covered in (chapter 4). It covered two main methodologies of field survey: questionnaire (section 4.4.3) and laboratory experimental tests (section 4.4).

On the basis of the research analysis of both experimental and field work as well as literature analysis the study concludes that there is a misunderstanding in the community that water bases are of less harm to human health in the United Arab Emirates. So this study started out with the aim of proving this theory; but the opposite was proved. No previous studies have been done in this field therefore information was quite scarce and based on theory and mouth talk. Concluded results from study can be summarized in several main points and issues as follows:

1. Different paint types are required for different building types of buildings with relation to the city of location and environmental factors that are advised to be considered.
2. It has been noticed from study results that paint materials are not the only factor playing a role in effecting human health and comfort of internal spaces. There are other factors effecting the hazardous health symptoms and diseases that appear on users in different building types such as: users suffering of them even before a paint job is done, pollution, climate, population, environment of space, temperature, humidity ventilation and many other factors as well.
3. In case of educational buildings it was found from user response analysis that it is most advised to use acrylic based paint in coastal and semi coastal regions of the country (ex. Abu Dhabi and Shahama cities), while water base paints were best used in desert regions (like Baniyas city).
4. In case of residential buildings it advised to be suitable to use acrylic paint in coastal and desert regions (ex. Abu Dhabi and Baniyas). Water base paint in semi coastal regions such as city of Shahama is suggested to be more appropriate
5. Amazing result were achieved from test samples, there are hundreds of paint trade marks available with a broad range of paint types and colors available on the market, but the

fact remains that they are all similar materials with slight difference in appearance or property.

6. Different test methods and sample techniques have been able to reveal the fact that there is no such thing as 100% environmentally friendly or hazard-free paints. But we can say there are less harmful paints on human health or of a less environmental impact.

5.3 Recommendations For Possible Improvements:

1. It is wisely advised that paint manufacturers are to be notified of study concluded results in hope that such materials will be developed in respect to country health regulations and environmental aspects taken into in consideration during manufacturing process of any paint type.
2. It is suggested that the manufacturing of paints is to be in association with environmental regulations stated specifically with the U.A.E. environment (or similar environments) with relation to environment associations or groups examples of the ERWDA (environmental research and wild life development agency) or friends of the environment group.

5.4 General Recommendations:

This section gives consideration to recommendations and suggestions of how study obtained results may be helpful in the community and especially into buildings constructed under the regulations of local government departments or ministries in the emirate or also on the level of the country such as the works department in Abu Dhabi.

These suggestions can be done on 3 levels of the community: local government authorities and environmental organizations & associations, population of the community, paint manufacturers.

- Government authorities in coordination with environmental associations and organizations:

1. It is seen to be a necessity for Government authorities and local departments to be highly aware and careful that paints used in any building type are according to health specifications of the city and building type before building permits are released. It's also advised that this takes place whether or not these projects are executed for the government or private. This is expected to be done in coordination with environmental associations and associations on the local and international level.
2. It is highly advised that site engineers and other concerned engineers are to be trained to raise their level of knowledge in building materials (including paints and their types) and

their effects on human health. This may enlighten them on the importance of their role of keeping things into perspective of human health and the environment.

- Manufacturers, contractors and building material suppliers:

1. It's believed that enhancement of fines on contractors, suppliers and manufacturers who don't follow government paint material (or any other building material) specifications approved and standardized by local or higher government authorities such as from government departments, ministries or environmental organizations...etc.
2. it is believed to be highly effective that fines are to be enhanced on paint manufacturers, suppliers or contractors using paints (or any other building materials) that are without written information on hazards :
    a. Flammability/ Combustibility:
    b. Solvent toxicity:
    c. Safe use of: Inhalation, Ingestion, Skin Contact, Storage instructions and regulations.
    d. Protecting The Environment By Good Formulation
    e. Toxicity And Environmental Pollution:
3. it is suggested that all paint materials (or any other building materials) not following legal authorized specifications implied by local authorities and in coordination with health and environment groups and foundations are to be banned from construction use immediately. But this recommended to be done only after warning.

- Community population:

1. Encourage user awareness on paint finishing materials and how to choose them according to design requirements and building use with other concerned aspects in consideration and not select just according to taste and desire or economic reasons or factors.
2. It is seen to be important that user awareness may be required of first aid procedure when dealing with any paint type and it should be handed out by manufacturer with assurance of government authorities.

5.5 Suggestions For Future Research And Development:

1. It is suggested that further more detailed can be carried out on paint materials and their types (or other building materials) with consideration to environmental aspects. , to provide more accurate and most safe and healthy space environment for various building envelopes. It is advised that this is carried out with aid and coordination of government

authorities and environmental associations such as: friends of environment association, Environmental Research and Wildlife Development Agency (ERWDA) ...etc.

2. It may be wise to encourage the carry out of further studies on other factors that might have effect on how paint materials may enhance hazardous effects of different building users should thoroughly and carefully be done with aid of specialists in this field both on the local and international levels. Examples of these studies are to be related to climate (temperature, location, urban activities of the city, building use, ventilation, etc.). This encouragement can be in form of financial grants, scholarships awards etc.
3. It may be very effective if a material standard specification encyclopedia be written out related specifically with United Arab Emirates environment and health information taken into consideration, similar to standard specifications used on international level...
4. It is recommended that a material standard specification encyclopedia be written out related specifically with United Arab Emirates environment and health information taken into consideration, similar to standard specifications used on international level.
5. It is suggested that urban development plans are to be according to suitable geographical distribution and design stage with consideration to suitable material selection to use with respect to building location and activity type.
6. Users are to be aware of first aid procedure when dealing with any paint type and it should be handed out by manufacturer with assurance of government authorities.

Appendices:

- *Appendix 1*
- *Appendix 2*
- *Appendix 3*
- *Appendix 4*
- *Appendix 5*

Computer Programs:

The computer programs mentioned in the text are listed in this appendix A summary of the programs is given in table A 1

Table A1: Thesis Study Computer Programs

Program	Program Function
Microsoft Office Word- XP Home Edition	Typing all thesis text literature
Microsoft Office EXCEL- XP Home Edition	Configuration of numerical data achieved from questionnaire into bar graphs
Microsoft Office Power point - XP Home Edition	Presentation of flow charts and drawn figures
WCAS	The interpretation of concentrations of components, gas and fumes released from paint materials into linear or parabola graphic waves. A library of known materials, the spectrum of an unknown can be identified by comparison to a library of known compounds WCAS has several infrared spectral libraries including on-line computer libraries

Study Difficulties

The whole thesis study took about 3 years to be totally completed It was done on several stages due to the difficulties that were faced during time of study which can be summarized in the following main points

- The thesis topic was new and considered unique in the U A E which caused difficulty in getting information from related government departments, ministries or authorities
- Lack of literature resources in public libraries because most of them were concerned on paint application methods and paint main ingredient contents and toxicity but none really related it with a direct study to human health. Those resources that were were old and not upto date.
- Information on the internet wasn't official or needed registration to be admitted Those that were open to public were more commercial sites than data sites. Not all sites on the web can be depended on to be accurate and correct
- Secrecy of the trade prevented paint manufacturers from giving exact information about paint material content ingredients, composition, hazardous effects.
- Author was a part time student- working in Abu Dhabi works department- chief assistant for minor projects in the technical service department
- CLU in Alain University had a tight schedule, several other tests were being carried on by academic staff members, students and authorities, which made it difficult to cover all required samples in a short time period.
- The FTIR was air cooling type which required 6 hours to test and cool the sample in order to accept a new sample and there was over 100 samples to be made and done
- Difficulty of transportation between CLU located in boys Jeemi Campus and girls campus due to university regulations. Permissions required 2-3 weeks to be gained

Experimental tests done on paint samples:

In this thesis study "Paints and Their Environmental Impacts on Human Health in the U.A.E" over 100 paint samples were done on jotun manufactured paints. This particular trade mark was chosen over other paint trade marks available in the building material market because it's approved by local authorities and departments and maintenance manuals. In addition to that its one of the most popular paint materials used in construction as well as it being the most expensive. With these given inputs it was assumed that it must be top quality paint.

With the cooperation of the jotun paint manufacturer located in the Musafah area, author was supplied with several different types of paint types & paint thinners to perform laboratory tests on. These paints and thinners are stated in table A3.1 as follows:

Table A3.1 Paint Types , Uses, Information & Technical Data Information

Product Name	*Recommended Use*		*Technical Information*		*Application Data*						*Typical Recommended Paint Systems*	
	Interior Surface	*Exterior Surface*	*Solids % By Volume*	*Flash Point °C*	*Application Methods*				*Mixing Ratio*	*Thinner/ Cleaner*	*Type of coat*	*# of coats*
					Airless Spray	Brush	Roller	Conventional Spray				
Bengalac Gloss	■		38+ 2	40 + 2	■	■	■	■	Single Pack	Thinner #2	Acrylic Emulsion Primer Stucco Bengalac Gloss	1 2 2
Stucco	■		52+ 2						Single Pack	Water	PVA Primer Stucco Jolly Fix/Durosan/ Fenomastic	1 2 2
Acrylic Emulsion Primer	■	■	32+ 2		■	■	■		Single Pack	Water	Acrylic Emulsion Primer Texo Compound Weathertough / Jotacryl / Durathane /Futura	1 1 2
Fenomastic Primer	■		25+ 2		■	■	■	■	Single Pack	Water Max 5%	Fenomastic Primer Stucco Fenomastic Gold	1 2 2
Stucco	■		52+ 2						Single Pack	Water	PVA Primer Stucco Jolly Fix/Durosan/ Fenomastic	1 2 2
Fenomastic Gold	■		38 + 2		■	■	■	■	Single pack	Ready to Use	Fenomastic Primer Stucco Fenomastic Gold	1 2 2
Jotacote 412			100.0	>100	■	■	■	■	2 parts comp. A (BASE) 1 part comp. B(Hardener)	Thinner # 4 / Thinner # 17	Jotacote 412	2*25mic.
Jollyfix			32+2		■	■	■	■	Single Pack	Water	PVA primer Stucco Jollyfix	1
PVA Primer			16+ 2		■	■	■	■	Single Pack	Water	PVA Primer Stucco Jollyfix/ Durosan/ Fenomastic	1
Stucco			52+ 2		■	■	■	■	Single Pack	Water	PVA Primer Stucco Jolly Fix/Durosan/ Fenomastic	1

Table A3.1 Paint Types , Uses, Information & Technical Data Information

Product Name	Recommended Use		Technical Information		Application Data						Typical Recommended Paint Systems	
	Interior Surface	Exterior Surface	Solids % By Volume	Flash Point °C	Application Methods: Airless Spray	Brush	Roller	Conventional Spray	Mixing Ratio	Thinner/ Cleaner	Type of coat	# of coats
Durathane	■	■	48 +2	31+ 2			■	■	9 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #10	Acrylic Emulsion Primer/ Tex primer Pengaurd HB (dilute 25-30% thinner #17) Pengaurd Texo Durathane	1 1 1 2
Acrylic Emulsion Primer	■	■	32+ 2		■	■	■		Single Pack	Water	Acrylic Emulsion Primer Texo Compound Weathertough / Jotacryl / Durathane / Futura	1 1 2
Pengaurd HB	■	■	54+ 2	25+ 2	■	■	■		4 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #17	Pengaurd HB Pengaurd Texo (dilute 25-30% thinner #17) Durathane/ futura	
Pengaurd Texo	■	■	62+2	25+ 2		■	■		4 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #17	Pengaurd clear sealer (dilute 25-30% thinner #17) (for concrete) Pengaurd HB Pengaurd Texo Durathane	1 1 1 2
Pengaurd clear sealer	■	■	44+2	25+ 2	■	■	■		4 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #17	Pengaurd clear sealer (for concrete) Pengaurd HB Pengaurd top coat	1 1-2 100mic. 1-2 40mic
Pengaurd HB					■	■	■		4 parts comp. A (BASE) 1 part comp. B (Hardener)	25% Thinner # 17	Pengaurd HB Pengaurd Texo (dilute 25-30% thinner #17) Durathane/ futura	
Acrylic Emulsion Primer	■	■	32+ 2		■	■	■		Single Pack	Water	Acrylic Emulsion Primer Texo Compound Weather tough/Jotacryl/Durathane/Futura	1 1 2
Pengaurd Texo								■	4 parts comp. A (BASE) 1 part comp. B (Hardener)	25% Thinner # 17	Pengaurd clear sealer (dilute 25-30% thinner #17) (for concrete) Pengaurd HB Pengaurd Texo Durathane	1 1 1 2
Pengaurd clear sealer	■	■	44+2	25+ 2	■	■	■		4 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #17	Pengaurd clear sealer (for concrete) Pengaurd HB Pengaurd top coat	1 1-2 100mic. 1-2 40mic
Durathane	■	■	48 + 2	31+ 2			■	■	9 parts comp. A (BASE) 1 part comp. B (Hardener)	Thinner #10	Acrylic Emulsion Primer/ Tex primer Pengaurd HB (dilute 25-30% thinner #17) Pengaurd Texo Durathane	1 1 1 2
Jotacryl	■	■	34+ 2	25 +2	■	■	■	■	Single Pack	Thinner #7	Acrylic Emulsion Primer/ Tex Primer Texo Compound Jotacryl	1 1 2
Texo Compound			62+ 2					■	Single Pack	Water	Tex Primer/ Acrylic Emulsion Primer Texo Compound Durathane / Futura	1 1 2
Acrylic Emulsion Primer	■	■	32+ 2		■	■	■		Single Pack	Water	Acrylic Emulsion Primer Texo Compound Weathertough /Jotacryl / Durathane/ Futura	1 1 2
Jotacryl	■	■	34+ 2	25 +2	■	■	■	■	Single Pack	Thinner #7	Acrylic Emulsion Primer/ Tex Primer Texo Compound Jotacryl	1 1 2
Texo Compound			62+ 2					■	Single Pack	Water	Tex Primer/ Acrylic Emulsion Primer Texo Compound Durathane / Futura	1 1 2
Tex Primer	■	■	40+ 2				■	■	Single Pack	Water	Tex Primer	1

In order to be able to test the samples of these paint materials they were applied on glass plates of a (40*40*.8) cubic cm glass plate. These plates were then divided with marker pens into smaller slide portions (5*10 sq.cm) for ease of stacking and transportation and each slide was labelled on the back with sample name or code. Each slide on the plate was covered with a layer of paint samples. 1st pure samples of the paint component and then standard layer composition as in practical use.

There were 4 paint test plates prepared in the beginning of this part of the experimental stage. Each was to be located in different locations: CLU, Abu Dhabi, and Baniyas & Shahama. The aim of this was to observe whether the difference of city environment had any effect on the change or final paint material. A scratch powder was taken from each sample every

All paint samples undercoats, topcoats and thinners mentioned in the above tables were tested in 3 different phases: fresh from can samples, 2 weeks after drying, 1month after drying. Test results observed from the tests run on these pure and composition samples gave similar components when tested at different phases with only one difference whether it was an oil base paint or a water base paint. This difference was that the solvent (in case of water paints) or solvent (in case of oil base paint) evaporated when temperature in the TGA device started to increase with a rate of 10 degrees/ minute for 20 minutes, and hardly any could be detected after paint was fully dry. Otherwise no recorded difference could be detected with the TGA, FTIR or FTIR/TGA.

The other fact concluded from the many repeated results was that there was hardly any difference in paint ingredient components. They were almost all the same with the only difference being that they were either water base or oil base. In this case we can come to the conclusion that different paint types, commercial trade mark names all represent the same material, but for commercial reasons they have been given different names to distinguish between them either by: color or texture (relative to pigment size, shape, etc.).

The components that were found in each phase of the raising temperature tended to show in the form of linear graphs that showed an rising increase in component intensity at the beginning of the phase followed with a similar decrease after reaching its peak and the phase stage is stated to end when carbon dioxide appears relating the end of one component and appearance of another.

This a similar form available with both water base paints and oil base paints with the difference in the 1st components released at beginning of the test which as mentioned earlier that in water vapor in water base paints while we find the used solvent or thinner used in oil paint mixture.

For more information concerning the components and substances obtained from test analysis reader is advised to see section 4.6 of chapter 4 which discusses the details of the experimental laboratory tests that were accumulated and the results obtained from them with a summary on the health hazards and technical information related to each of them.

Alkyds:

These are a class of branched polyesters and form an insoluble thermosetting film formed by condensation polymerization.

Emulsion:

Emulsion paints, which also have an alternative name "latex paint", are paints that consist of 2 parts the dispersed phase and the continuous phase. In other words it is "a paint of which suspension of one liquid within another" as emulsion paints carry suspended solids such as pigment resins in a liquid medium, they may be more correctly termed scientifically as a " latex", and classified as a milky fluid with substances in suspension"(Yvonne dean, 1989). The viscosity of an emulsion is a litter greater than that of a continuous phase. It is not influenced by dispersed polymer concentration only at high concentrations. So if the film former can be emulsified, then according to principles the paint can be supplied as an emulsion at much higher solids than would be the case for a solvent borne paint (J.Bentley & G.P.A Turner1998).

Fillers:

Are a smooth paste used for filling slight surface imperfections. These kinds of coatings can be either clear or pigmented and are formulated to act as a barrier coat. These coats can be used for the following purposes:

- Prevention of bleeding
- Protection of paint films or a substance from being softened or swollen by solvents in sequent coats
- Reduction of surface suction ((R. Woodbridge, 1991).

These kind of paint coatings are divided into universal fillers for walls and wood, to be finished by painting; plaster fillers; wood fillers for wood to be painted; and natural wood fillers for wood to have a clear finish.

Universal Fillers:

May be ready mixed or be in powder form to be mixed with water. They are simply pressed into place and smoothed down. When dry they can be sanded flat. They are used for both interior and exterior surfaces and used almost all surfaces. They are known to be flexible, waterproof and are very hard when they set (A. Fulcher & B.Rhodes, 1991). They are more flexible than any other primer or filler.

Primers:

A primer is the first "glue like", pigmented coat that acts as the interface between the finished coat and the substrate. It must be wet and penetrable to achieve substrate adhesion, while ensuring compatibility with the finishing coats (Michele & Irene ash, 1978).

Plaster Fillers:

They are for used for walls only and are cheaper and can be used for quite large-scale repairs

2-Part Epoxy-Based Fillers:

These fillers are available for wood and metal filling. They are very quick setting and strong and they have the advantage of being ideal for rebuilding rotted wood as part of wood repairing material systems. But still they must be finished by paint.

Foam Fillers:

This type of filler is for insulating and gap filling, very ideal for using around pipes and gaps between timber frames and walls. They expand as they set (John McGowan & Roger Durben, 1990)

Plastic Wood:

Is a wood colored and useful for filling small holes and cracks in wood.

Wood Stopping:

Is filler available in a wide range of wood shades (John McGowan & Roger Durben, 1990).

Primers:

Are the 1st coats of a paint system and are used to help provide good adhesion to the paint film used as a top coat for the intended non-porous substrate. For substrates that are porous the main need for a primer is to prevent the excessive absorption of later paint coats

Surfacers:

Are paints with a very heavy pigment formulation needed to fill minor surface irregularities? It is applied like a paint but usually by the spraying method but also can be applied with the aid of a brush as well; it is usually sanded before finishing coats can be applied, but new sealers have now appeared on the market that do not to be sanded out such as "stoppers".

Stoppers

Are Surfacers that are in the form of paste like materials intended to fill holes and cracks in a surface that is to be painted. These paints are applied with a knife and sanded smooth after drying as mentioned previously. ((R. Woodbridge, 1991).

Table A4.1 Boiling Points, Flash Points And TLV's For Some Common Solvents

Solvent		BP °C	FP °C	TLV (ppm)
Ketones	Acetone	57	-17	750
	Methyl Ethyl Ketone	80	-4	200
	Methyl Isobutyl Ketone	116	13	100
	Di acetone Alcohol		54	50
	Di Isobutyl Ketone		47	
Esters	Ethyl Acetate	77	-3	400
	Isobutyl Acetate		16	
	N-Butyl Acetate	127	25	150
	2-Ethoxyethyl Acetate	156	52	50
	2-Butoxyethol Acetate	1	115	
Alcohols	Methanol	65	10	200
	Ethanol	78	12	1000
	N-Propanol	97	22	200
	Isopropanol	82	10	400
	N-Butanol	118	33	50
	Isobutanol	108	27	50
	Sec Butanol	100	14	
Hydro-Carbons	Toluene	111	5	100
	Xylene	138-144	24	100
	White Spirit	155-195	39	500
	SBP6	138-165	28	-

Data Source: R. Lambourne, 1987)

Neoprene		Air or heat	Excellent		Primer required		

Data Applied From: G. A. Harper, Ed., Handbook Of Paints And Varnishes, McGraw-Hill Book Company, New York 1975

Table A4.2 Properties Of Typical Polymeric Coatings

Name	*Application Method*	*Curing Method*	*Moisture Resistance*	*ax F Contin.*	*Adhesion To Metals*	*Flexibility*	*Typical Users*
Alkyd	Spray, Brush, Dip	Air dry	Poor	00	Excellent	Fair	Auto enamel
Epoxy-Phenol	Spray, Dip	React, bake	Excellent	00	Excellent	Good	Electric insulation
Floure-carbon	Spray, Dip	Fusion from solvent	Excellent	00	Excellent with primer	Excellent	High temp cook ware
Phenolics	Spray, Dip	Heat	Excellent	50	Excellent	Fair	High bake coatings
Nylon	Flame, Spray	-	Fair	50	Excellent	Fair	Low friction bearing
Polystyrene	Spray, Dip	Evaporation of solvent	Good	60	Excellent	Fair	Coil coatings
Polyurethane	Spray, Brush, Dip	Air dry	Good	50	Poor	Good	Furniture
Silicone	Spray, Brush, Dip	Air dry to bake	Excellent	00	Good with primer	Excellent	Heat resisting coating
Vinyl Chloride	Spray, Dip & Roller	Air dry	Good	50	Excellent	Excellent	Can coatings, furniture
Elastomers Butyl Rubber	Usually Spray, brush, dip for Elastomers	Air dry	Excellent		Excellent for all Elastomers	Elastomers used where high flexibility is required	Superior replacement for natural rubber
Chloroprene Rubber		Air dry	Excellent	90			Protection for sportswear
Flour Elastomers		Air dry	Excellent	50			Maintenance coating in hostile environments

Table A4.3 Pigment Colors, Sources, Origin, Properties And Usage

	Pigment	Origin			Specific Gravity	Opacity	Tinting strength	Resistance To			Characteristic	Principal use
		Earth	Organic	Inorganic				Alkali	Acid	Light		
Yellows	Yellow Red Chromes				.6		3			-5	Unsuitable for water paints & are toxic	Tinter for oil paints
	Zinc Chromate				.4		4				Rust inhibitive	Metal primers
	Ochre				.9		4				Tends to retard drying	Tinter for all paints
	Iron Oxide Yellow				.1		3				Excellent fastness on weathering	Ideal for finishing paints
	Unsa Yellow IOG				.6		3				Excellent fastness on exposure	Decorative paints only
Metallic	Micaceous Iron Oxide										Leafing properties	Paints for primed steel work
	Aluminum Powder				.6						Leafing or non-leafing types	Sealers & heat resisting paints
	Bronze Powder				.9						Tarnishes on exposure	Decorative metallic paints
	Zinc Dust										Protects iron and steel	Zinc rich paints
	Metallic Lead				1.4						Rush inhibitive Settles on storage	Metal primers
Browns	Raw Umber						3				Semi-transparent	Scrumbles glazes and tinters
	Burnt Umber				.5		3				Completely stable	Tinter for all paints
	Vandyke Brown				.5		4				Brittle and transparent in oil	Water color graining
	Burnt Sienna				.5		4				Completely stable	Tinter for all paints
Greens	Methalocyanine Green				.2		All types of paint				Completely stable	All types of paint
	Solid Chrome Green				.2		All types of oil/alkalis finishes				Turns blue on exposure Heat resistant Loses gloss on weathering Fades in absence of light	All types of oil/alkalis finishes
	Chromium Oxide Green				.1		Chemical and heat resistant paints					Chemical and heat resistant paints
Blues	Ultramarine				.3		Tinter for all paints					Tinter for all paints
	Prussian Blue				.8		Tinter for oil/alkyd paints					Tinter for oil/alkyd paints
	Methalocyanine Blue				.6		All types of paint				Completely stable	All types of paint
Reds	Orange &Scarlet Chrome				.1		Tinter for undercoat and gloss			-5	Unsuitable for water paints	Tinter for undercoat and gloss
	Red Iron Oxide				.4		2				Affected by heat	Decorative finishes
	Red Lead				.1		3				Stable	Finishing paints
Brown	Carbon Black				.8		2				Brown undertone	Black gloss finishes
	Amp Black				.8		3				Blue undertone	Tinters for all paints
	Graphite				.2		5				Leafing properties	Anti-corrosive paints
Whites	Titanium dioxide				.2		1				Titanium dioxide	In most paints
	Zinc oxide				.6		3				Zinc oxide	Fungicidal paints
	White lead				.7		3				White lead	Exterior wood primers
	Calcium plum bate				.7		3				Calcium plum bate	Primers for wood and galvanized iron
	Zinc phosphate				.3						Zinc phosphate	Metals and some types of universal primer

Data obtained: A. Fulcher & B.Rhodes, 1991

Table A4.4 Anticorrosive Pigments

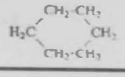
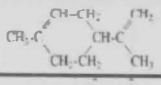
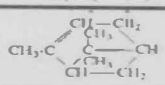
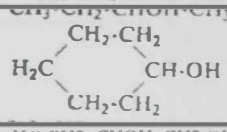
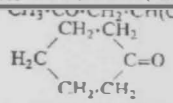
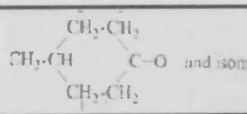
Class	Name	Notes
Inorganic Salts	*Basic lead Silico-chromate*	Dull orange pigment Low tinting strength allowing it to be used in admixtures with coloring pigments at all levels in the coating system to provide corrosion protection. Widely used for coatings for both the structural steel industry and for automotive paints Less toxic then the traditional red lead pigment
	Basic lead sulphate	White synthetic pigment. Moderate tinting strength which does not affect the flow properties of the liquid paint Can be used at all levels in a coating system Use in is limited due to color change. For they tend to darken in polluted atmospheres and this in addition to the toxicity of the pigment Its primary use is for anti-corrosive coatings for steel, particularly in marine environments
	Calcium Plumbate	Synthetic pigment of a white color when pure but its usually of a buffed color Basically in nature it reacts with acidic paints to yield lead soaps which have an inhibitory action They have a reinforcing effect on the mechanical properties of the film Most effective pigment in primers on zinc or galvanized iron surfaces Toxicity limits its applications in modern technology
	Read Lead	Still highly used world wide especially in heavy-duty maintenance coatings for structural steel, due to the formation of soap that give high adhesion and toughness to the film.
	Zinc (Potassium) Chromate	Are used for both decorative and industrial general purpose metal primers Is found basic in nature and this limits its use in acidic paint media
	Zinc Phosphate	Non-basic Non-toxic White colored pigment which allow the wide production of white or pale primers They can be used in aqueous and solvent thinned systems They are increasingly employed as a result of proven performance, due to their ability of being applied in any paint media Virtually insoluble, therefore they do not leach from paints as do more soluble salts as zinc chromate The mechanisms of its protection action are uncertain.
	Zinc Tetroxy-Chromate	Yellow synthetic pigment Used4 metal pretreatment primers "wash primers" for aluminum surfaces especially for aircrafts where other materials have are not applicable Less soluble than zinc chromate & has a protective action and is an adhesion promoter
Metals	*Stainless Steel*	An alloy of iron (chromium + nickel+ various minor alloying elements) Hard but ductile corrosion resistant being due to the presence of a complex oxide surface film When used as a pigment the film is corrosion protected though the mechanism of this is uncertain may provide a decorative effect particularly because the metal itself is essentially non-reactive in the paint media
	Aluminum	Resistant to many aggressive agents by the presence of a surface film of alumina Available in 2 forms leafing* & non-leafing *grades.
	Lead	Heavy meal able metal Chemically resistant to many chemicals, due to the formation of protective surface oxide and salt films Used in paints based on linseed oil, for the preparation of protective primers for steel work High addition levels are used and because of the high density of lead settlement can be a problem during storage of the liquid paint
	Zinc	An electropositive metal, chemically reactive Used in paint technology for the preparation of rich-zinc protective primers for steel work They function as an efficient anti-corrosion coating High level of zinc addition can lead to settlement problems during storage of the liquid paint

Data Source: J.Boxall & J.A.Von Fraunhofer 1980, R. Woodbridge, 1991

* Leafing Grade: tend to float to the surface of a paint film and become oriented parallel to the plane of the film

* Non-Leafing Grade: do not immigrate to the film surface but are more randomly distributed within the film and their main function is to provide a decorative sparkle effect to the coating

Table A4.5 Solvent Properties

Solvent		Formula	Solvency		Viscosity At 20 C	Boiling Point C	Flash Point(Closed Cup)C
			H-Bonding Group	Solubility Parameter			
Water		H2O	III	47.7	1.002	100	None
Aliphatic Hydrocarbons	Cyclohexane		I	16.	0.89a	81	3
	White spirit		I	15.1	1.09a	155-195	33
	Odorless white spirit		I	14.1	1.38a	180-207	55
Terpenes	Dipentine		I	17.3	0.975a	175-190	32
	Turpentine		I	16.5	1.26a	150-170	33
	Pine oil		I	17.5	6-26a	195-220	74-88
Aromatic Hydrocarbons	Toluene	C6H5 CH3.	I	18.2	0.55a	111	4
	Xylene	C6H4 (CH3.) 2	I	18	0.55a	138-144	27
	Styrene	C6H5 CH=CH2	I	19	0.586	146	31
	Vinyl toluene	CH3.C6H4.CH=CH2	I	-	0.77a	164-170	32
Alcohols	Methanol	CH3.OH	III	29.6	0.547	65	12-14
	Ethanol	C2H5 OH	III	25.9	1.2	78	14
	n-Propanol	CH3. (CH2) 2 OH	III	24.3	2.25	97	15
	Isopropanol	(CH3) 2 CH. OH	III	23.5	2.4	82	12
	n-Butanol	CH3. (CH2) 3 OH	III	23.3	2.948	118	35
	Isobutanol	CH3. CH (CH3) CH2OH	III	22.0	3.76	108	25
	Sec-Butanol	CH3. CH2. CHOH. CH3	III	23.3	3.15	100	24
	Cyclohexanol		III	-	52.7a	162	68
	Ethylene glycol	HO.CH2. CHOH. CH2.OH	III	29	17a	198	111
	Glycerol	CH2 OH. CHOH. CH2.OH	III	33.7	494b	290	160
Esters	MethylAcetate	CH3. CO.O.CH3	II	19.6	19.6	57	-9
	Ethyl Acetate	CH3. CO.O.C2H5	II	18.6	0.455	77	-4
	Butyl Acetate	CH3. CO.O.C4H9	II	17.3	0.671a	127	23
	Methoxypropyl Acetate	CH3. CO.O. CH (CH3) CH2. O.CH3	II	18.8	1.2	140-150	46
Ketones	Acetone	CH3. CO. CH3	II	20.4	0.316a	56	-17
	Methyl Ethyl Ketone	CH3. CO. C2H5	II	19	0.42a	80	-4
	Methylisobutyl Ketone	CH3. CO. CH2 .CH (CH3) 2	II	17.1	0.456a	116	16
	Cyclohexanone		II	20.2	1.94	157	47
	Methyl Cyclohexanone	 and isomers	II	19	1.75	165-175	47
Ethers & Ether-Alcohols	Diethyl ether	C2H5. O.C2H5	II	155.1	0.233	35	-40
	1-methoxypropan-2-ol	CH3. O. CH2.CHOH.CH3	II	20.8	1.65a	120	38d
	1-ethoxy propan-2-ol	CH3. CH2. O.CH2. CHOH.CH3	II	18.4	1.68	132	43d
	2-butoxy ethanol	C4H9. O.CH2.CH2. OH	II	18.2	3.318a	171	61
	Diethyleneglycol (DEG)	HO. CH2.CH2. O.CH2.CH2. OH	III	18.6	30a	245-250	124
	DEG Monoethyl ether	CH3.O.CH2.CH2.O. CH2.CH2.OH	II	19.6	3.53a	194	93d
	DEG mono butyl ether	CH3. (CH2) 3. O.CH2.CH2.O. CH2.CH2.OH	II	20.4	4.74a	232	232d
Nitroparaffins	Nitro methane	CH3. NO2	I	25.9	0.62	101	35
	Nitro ethane	C2H5. NO2	I	22.6	0.62	114	28
	1-nitropropane	CH3.CH2.CH2. NO2	I	21.8	0.81	132	34d
Chlorinated Paraffin's	Methylene chloride	CH2.Cl2	I	19.8	0.425a	41	None
	Ethylene dichloride	CH2Cl. CH2Cl.	I	20	0.383	84	13
	1,1,1-trichlorethane	CCl3. CH3.	I	17.5	0.83	72-88	None

Data Source: J.Bentley & G.P.A Turner1998

Table A4.6 ***Properties And Use Of Natural Resins And Synthetic Resin***

Type	Name	composition	Properties	Use
Synthetic resins	Oil modified alky resin	***Containing over 60% of a drying***	Good flow High gloss Good flexibility Weather resistant Pale color Not alkali resistant	Used for some air drying primers Most undercoats Eggshell finishes Varnishes
		Modified to a gel or thixotropic structure	Good brush ability High gel strength Fast gel recovery rate Heavy film build Non-drip	Thixotropic paints
		Containing non-dry oils	Very slow/non-drying Pale color Soft	Plasticizers in cellulose paints
	Epoxy Or Epoxied Resins	2-pack or cold cure type	Excellent adhesion Excellent water resistance Excellent chemical resistance Excellent abrasion resistance Extremely hard film	Chemically resistant coatings Abrasion resistant coatings Water resistant coatings
		1-pack epoxy ester (modified with drying oils)	Chemical resistant, but much less than the 2-pack type	Maintenance paints for factories
	Polyurethane resins	2-pack or cold cure type	Extremely hard film Excellent weather resistance Excellent chemical resistance Excellent abrasion resistance Less alkali resistant than epoxy	Chemical Resistant Finishes Abrasion Resistant Coatings
		1-pack based on drying oils		Interior And Exterior Gloss Finishes Clear Wood Finishes
	Polyvinyl acetate (PVA) COPOLYMER		Good color Non yellowing Good flowing properties Good adhesion Good water resistant Alkali resistant Good external durability Good wash ability	Adhesives Emulsion Paints Masonry Paints
	Acrylic Emulsions		Excellent adhesion Water white color Non-yellowing Very good wash ability Alkali-resistant Very good external durability	Emulsion Paints Timber Primers Quick Drying Undercoats Adhesives Masonry Paints
	Phenolics Resins		Very good water resistance Alkali resistant Poor color Yellows badly	Alkali resistant varnishes Marine Varnishes Anti-Corrosive Primers
	Coumarone Resin		Alkali resistant Low acid value Tends to yellow	Alkali resistant paints Metallic paints
	Maleic Resin		Very pale in color Non yellowing Good gloss Poor resistance to chemicals	Combined with alkyd resins for non-yellowing paints Pale varnishes
	Urea/Formaldehyde Resin (2-Pack Acid Catalyzed)		Very poor color Non yellowing Hard glossy films Heat resistant	Clear lacquers for bar counters and furniture
	Silicon Resin		Water resistant Heat resistant up to 475°c	Clear waterproofing for bar counters & furniture
	Polyvinyl Butyral		Excellent adhesion	Etch primers
Natural resins	*Copal* Fossil resins obtained mainly from Congo		Very hard Pale color	Oil varnishes
	Manila Copal Fossil resins obtained from manila		Bleed resistant	Road marking paints
	Kauri Fossil resins obtained from new Zealand		Pale color Combines well with oil	Oil varnishes
	Damar Recent resin tapped from living trees in Malaysia		Very flexible	Cellulose lacquers Shellac varnishes
	LAC Recent resin obtained from excreta of tree feeding insects in India		Soluble in alcohol	Knotting Button polish French polish

Data (A. Fulcher & B.Rhodes, 1991

Table A4.7 Properties And Types Of Drying Oils And Their Use

Oil	Properties	Use
Linseed Oil **Is obtained from the seed of the lax plant**	Pale yellow in color Dries within 7days under good drying conditions Saponified hy the action of strong alkalis Darkens with age Limited water resistance Dark brown in color	Mixed with red or white lead for metal and timber primers Oil modified resin mediums Chemically combined with alkyd, epoxy and urethane resins
Boiled Oil **Linseed oil that is heated with driers added**	Dark brown in color Dries within 12 hours Improved water resistantant Compared with linseed oil Good adhesion Saponified hy the action of alkalis Darkens and becomes brittle with age	Oil modified resin mediums
Stand Oil **Is partially polymerized oil**	Pale yellow in color High viscosity Excellent flow Good flexibility Not alkali resistant	Oil modified resin mediums Some wood and metal primers Manufacture of alkyd resin
Soya Bean Oil	Pale yellow Very slow drying Does not darken with age Not alkali or water resistant	Combined with resins for use in alkali resisting and water resisting coatings
Tung **Or** **China Wood Oil**	Milky white in color Dries within 7days under good drying conditions Resistant to alkali and water	Chemically combined with resins use in alkali-resisting and water resisting coatings
Tobacco Seed Oil	Slow drying	Chemically combined with alkyd resins
Oiticica Oil	Similar properties to tung oil Pale yellow Very slow drying Does not darken with age Not alkali or water resistant	Sometimes used as an alternative to tung oil
Dehydrated Castor Oil	Can dry in under 5hours Pale color Non-yellowing	Chemically combined with alkyd epoxy resins

Data (A. Fulcher & B.Rhodes, 1991

Table A4.8	Metal Drier Additives
Metal	Notes
Cobalt	Most powerful drier, but its effect is primarily on the surface. Excess of cobalt drier leads to premature surface skinning and subsequent wrinkling of the surface. A typical level of cobalt drier is .05% of cobalt metal calculated on total resin solids Occasionally used on its own in aluminum dry paints and also in stoving paints
Lead	Traditionally the most commonly used metal A typical level of lead drier is .05% calculated on total resin solids Still used in combination with other metals unless toxicity or sulfide staining of the film rules out Though some other additives are being used as replacement for lead non have been able to prove effectiveness as well as lead.
Manganese	2nd most powerful drier after cobalt It contributes in both surface and through drying Its limitation is color: due to the change from manganous, light brown to dark brown the color of predominately manganic. Due to this they are used for undercoats and primers. Increased benefit is obtained the more amounts of manganese that are added which is not applicable to other driers used in paint manufacturing or application A typical level of manganese drier is .05% calculated on total resin solids
Zinc	Used as a soap or added as a zinc oxide pigment in drier quantities It slows the initial surface drying and accelerates the dry through The resulting film is harder when zinc is used
Calcium	Not a prime drier It's used as an auxiliary drier to a lead/cobalt drier system; because it helps prevent precipitation of the leadon storage. And drying at low temperature is improved A typical level of calcium drier is .2 % calculated on total resin solids
Cerium	A substitution for lead that was introduced a few years ago It has the problem of yellowing which discourages its use
Barium	It's used as an auxiliary drier to a lead/cobalt drier system; because it helps prevent precipitation of the lead on storage. And drying at low temperature is improved No general legislation on toxic hazard that is known of, but still the amount of it used in toys is strictly controlled Is applied in some lead free drier combinations, but concern exists for its long term future
Zirconium	Is regarded the prime replacement for lead as a typically .2 % calculated on total resin solids but Its drying mechanism is different and therefore it can not be regarded as a direct substitution Toxicity clearance has proven satisfactory
Vanadium	A substitution for lead that was introduced a few years ago It has the problem of yellowing which discourages its use Losses dry on storage No real usage
Aluminum	Sometimes recommended as a potential part replacement for lead Its use appears to be most effective when some modification of the resin is made to complement its effect Reference to suppliers is recommended before use
Data From: J.Boxall & J.A.Von Fraunhofer, R. Lambourne, 1987	

Table A4.9 Some Typical Primary Pigments

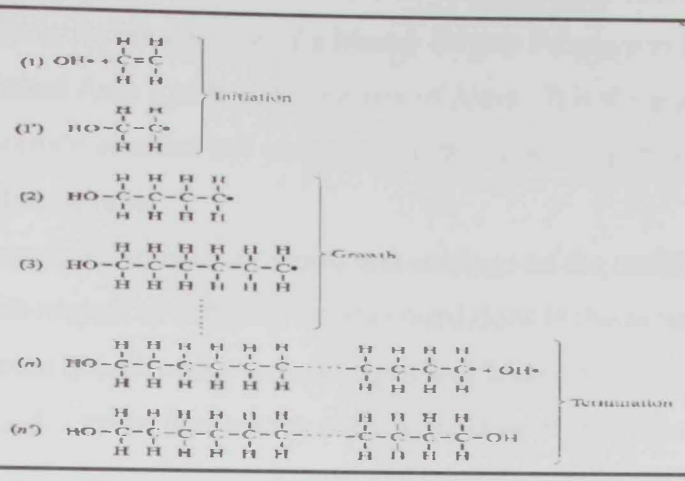
Color	Inorganic	Organic
Black	Carbon Black Copper Carbonate Manganese Dioxide	Aniline Black
Yellow	Lead Chromate Zinc Chromate Barium Chromate Cadmium Sulfide Iron Oxides	Nickel Azo Yellow
Blue/Violet	Ultramarine Prussian Blue Cobalt Blue	Phthalocyanin Blue Indanthrene Blue Carbazol Violet
Green	Chromium Oxide	Phthalocyanin
Red	Red Iron Oxide Cadmium Solenoid Red Lead Chrome Red	Toluidine Red Quinacridones
White	Titanium Dioxide Zinc Oxide Antimony Oxide Lead Carbonate (Basic)	-

Table A4.10 Some Typical supplementary Pigments (inorganic)

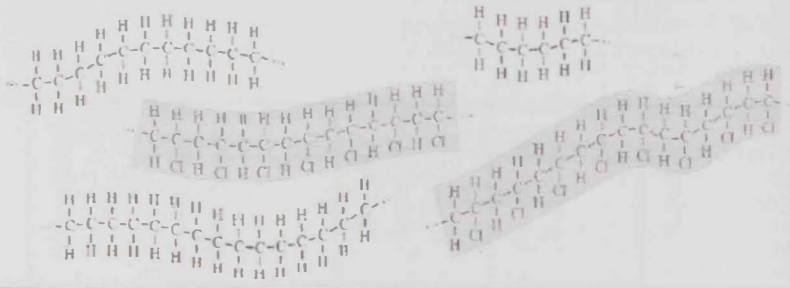
Chemical nature	Type
Barium sulphate	Barytes Blanc fixe
Calcium carbonate	Chalk Calcite Precipitated chalk
Calcium sulphate	Gypsum Anhydrite Precipitated calcium sulphate
Silicate	Silica Diatomaceous silica Clay Talc Mica

Figure A4.11 Various Common Polymer Chains

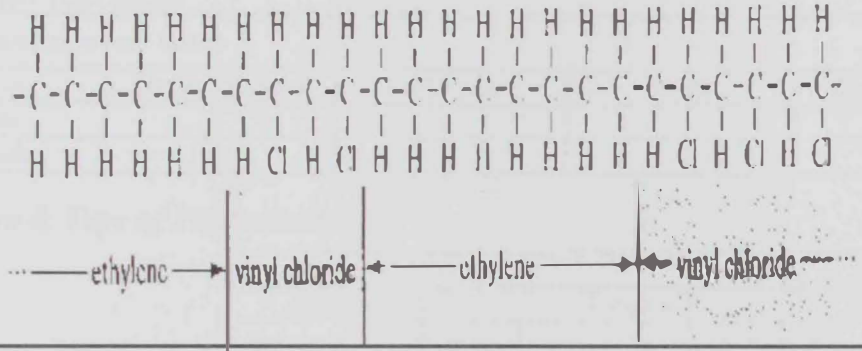
Chain growth



Block Copolymers.



Copolymer



Data obtained: Shackelford J. ,2000

Paints and Coatings and Their Environmental Impact on Human Health

The following questionnaire is for the purpose of a Master Degree Program in Material Science Engineering at the United Arab Emirates University in Alain. It is for academic use only and has no intention to intrude or effect any paint manufacturer or company of any kind.

The main aim of this questionnaire is:

Creating awareness for environmental impacts of paints and coatings on the health of human beings in hot arid climates with respect to different weather conditions in the same region.

Relating impacts concluded from questionnaire to paint types and function

Analyzing information from end users to find out the most suitable paint type for the U.A.E environment

1.1) Occupation:

Occupation	Technical/ Engineer Executive	Managerial	Professional	)Doctor, Lawyer, Etc(	Academic /Educator	Retired	Other

In case of other, please specify? _____

1.2) Sex/age status of house holder:

Sex/ age	Under 10 years	11-30 years	31-60	Over 60 years
Male				
Female				

2.1) Location & Type of Public Building

		Location							
		Abu-Dhabi		Baniyas			Shahama		
		East	West	East	West	Mafraq	Shaha ma	Bahia	Rahba
Type Of Building Function	Low cost houses								
	Educational Building								
	Health Care Building								
	OfficeBuildings								

2.2) Interviewer disease information In public buildings:

Building Type		Educational		Residential		
		Staff Offices	Class Room	Villa	Low cost	Apartment
diseases	Diabetics					
	Blood Hyper-tension					
	Allergic: Irritation Of Eyes					
	Allergic: Irritation Of Skin					
	Allergic: Skin Rash					
	Allergic: Runny Nose					
	Allergic: Reparatory Sys.Prob.					
	Other					

In case of other, please specify? _____

In the following parts of the questionnaire it is recommended that the user is to answer only one of the 3 following parts of which he/ she is concerned with acoording to the building function which they are related to and represent.

Part I: This Part Is Related To health care Building Users

3.1) Different Space Functions Finishing Materials/ residential type buildings

Types Of Finishing Materials Vs. Space Function				Offices	Services	Class Room
Walls	Artificial Finishes	Paint	Oil-base			
			Water base			
			Other			
			In case of other type of paint type finish, please specify?			
		Wall paper				
		Gypsum				
		Other				
			In case of other type of artificial finishes, please specify?			
	Natural Finishes	Wood				
		Stone				
		Other				
			In case of other type of natural finishes, please specify?			
Floors		Carpet				
		Concrete				
		Wood				
		Venial				
		Other				
			In case of other flooring finishes, please specify?			
Ceilings	Artificial Finishes	Paints	Oil base			
			Water base			
			Other			
			In case of other artificial paint finish, please specify?			
		Gypsum				
		Other				
		In case of other type of natural finishes, please specify?				
	Natural finishes	Wood				
		Other				
			In case of other natural finish, please specify?			

Part II: This Part Is Related To Educational Building Users

3.1) Different Space Functions Finishing Materials/ Educational

Types Of Finishing Materials Vs. Space Function				Offices	Services	Class Room
Walls	Artificial Finishes	Paint	Oil-base			
			Water base			
			Other			
			In case of other type of paint type finish, please specify?			
		Wall paper				
		Gypsum				
		Other				
			In case of other type of artificial finishes, please specify?			
	Natural Finishes	Wood				
		Stone				
		Other				
			In case of other type of natural finishes, please specify?			
Floors		Carpet				
		Concrete				
		Wood				
		Venial				
		Other				
			In case of other flooring finishes, please specify?			
Ceilings	Artificial Finishes	Paints	Oil base			
			Water base			
			Other			
			In case of other artificial paint finish, please specify?			
		Gypsum				
		Other				
		In case of other type of natural finishes, please specify?				
	Natural finishes	Wood				
		Other				
			In case of other natural finish, please specify?			

The following questions are for all public building types:

4.1) Financing Of Repaint Jobs	Yes	No
• Paint jobs as well as maintenance are done on the expenses of donators		
• The main owner does the financing for any maintenance in the building premises including paint jobs		
• No maintenance is ever done by either parties		
In case of other, please specify? _____		

4.2) Symptoms Apparent after Paint Jobs:

Symptoms apparent when entering a freshly painted room		Yes	No
▪ *Dizziness*			
▪ *Nausea*			
▪ *Coughing*			
▪ *Vomiting*			
▪ *Allergies*			
In case the answer is yes to allergies, please choose one of the following types?	Skin Rashes		
	Irritation Of Skin		
	Irritation Of Eyes		
	Respiratory problems		
	Other Signs		
	If there are other types, Please specify? 1. _____ 2. _____		

4.3) Type Of Paint, Preferred Trademarks That Caused Side Affects:

Type Of Paint that caused side affects	Yes	No
Oil-base paint (solvent)		
Water-Base Paint		
Other Kind Of Paint, Please Specify which type and why? _____		

4.4) Paint Colors and Room Affects:

Favorite Colors	Red	Blue	Yellow	Orange	Black
Do you prefer any of these paint colors					
If answer any other preffered, please specify which color and why? _____					

Room Comfort		
Have you ever entered a room and felt uncomfortable?	*Yes*	*No*
If answer is yes, please specify why? _____		

Symptoms Apparent For Uncomfortable Room Space	YES	NO
There are difficulties in breathing		
It makes me feel sick: vomiting, nausea, dizziness, etc.		
Other, please specify exact feeling? _____		

Any extra comments you would like to add, will be greatly appreciated?

_____

_____

**** *Thank You* ****

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الخلاصة

الدهانات وآثارها البيئيةعلى صحة الإنسان بدولة الإمارات العربية المتحدة

Paints and Their Environmental Impacts on Human Health in the U.A.E

قدمت هذه الدراسة كجزء من متطلبات برامج ماجستير علوم و هندسة المواد بجامعة الإمارات العربية المتحدة. تناول البحث موضوع الدهانات وتأثيراتها البيئية على صحة اللإنسان بدولة الإمارات والتي الإفتراض عند بدء الدراسة إنها أحد مواد تشطيبات المباني ذات تأثيرات سلبية على الصحة.

حضر مناقشة الإطروحة الدكتور هادف العويس عميد الدراسات العليا بالجامعة ولجنة المحكمين المكونة من المشرف على الرسالة الدكتور محمود حجاج والممتحن الداخلي الدكتور عبدالله الشامسي والممتحن الخارجي الدكتور دنيس لفداي من جامعة لافبرا ببريطانيا.

دارت الدراسة حول محولة ايجاد الآثار السلبية للدهانات في البيئات المختلفة بالدولة وإنعكاس ذلك على صحة مستخدمين المباني المختلفة. تكمن صعوبة البحث في قلة الدراسات المشابهة وندرتها وكذلك قلة الوعي العام حول مواد التشطيبات وآثارها الممكنة. لذا أجريت الدراسة على 3 اوسس علمية تشمل:

- المصادر العلمية المختلفة
- البحث الميداني ويتكون من مرحلتين:
  - اللإستبيان والذي غطى المباني التعليمية والسكنية بثلاث مدن من إمارة أبوظبي (ابوظبي (ساحلية)،بنياس (صحراوية)، الشهامة (شبه ساحلية) ز من الجدير بالذكر أن هذه المدن أخذت على سبيل المثال لا الحصر.
  - التحاليل المخبرية للمختلف أنواع الدهانات المائية والزيتية والأكريلك والتي أجريت في المختبر المركزي بالجامعة والحاصل على شهادة الأيزو

وقد توصلت نتائج البحث إلى أن أغلبية الدهانات ماهي إلى مواد متشابهة تختلف بأسمائها التجرية لاالتكوينات الداخلية. ونتج عن الدراسة كذلك حقيقة أن هناك عوامل أخرى بالغة الأهمية لها دور سلبي على الإنسان ولايمكننا الفصل بأن الدهانات هي وحدها المؤثرة على مستخدمين المبانيز ومن هذه العوامل الرئيسية المؤثرة : الموقع الجغرافي، الطابع البيني للمنطقة، نوع نشاط المباني، التلوث... إلخ. وعلى ذلك الأساس توصلت الإطروحة إلى أفضلية إستخدام بعض الدهانات عن غيرها في مناطق دون غيرها والعكس صحيحز فعلى سبيل المثال يفضلفي المباني التعليمية إستخدام الدهانات الأكريليكية بالمناطق الساحلية والشبه ساحلية، الدهانات المائية للمناطق الصحراوية. اما بالنسبة للمباني السكنية فيرشح إستخدام الدهانات الإكريليكية في كل من المناطق الصحراوية والساحلية، اما المناطق الشبه ساحلية فيفضل إستخدام الدهانات المائية

إن من التوصيات التي جاءات بنهاية الدراسة انه من الضرورة أن يتم إعلام مصنعين الدهانات بنتائج البحث حتى يتمكنو من تطوير منتجاتهم بما يتلاءم مع البيئات المختلفة بالدولة وصحة الإنسان. وأيضا تم التوصية بضرورة ماندة الدوائر والوزارات الحكومية للدراسات المشابهة حول مواد البناء المختلفة وكذلك العوامل المؤثرة بها، و تم الإشارة إلى مدى ضرورة وأهمية تبني ودعم الهيأت والمؤوسسة البيئية لمثل هذه الدراسات والتنسيق مع الحكومة بذلك.

وفي النهاية أقرت لجنة التحكيم بالجهد المبذول في جمع المعلومات والتوصل إلى نتائج وتوصيات الدراسة خاصة الجزء التطبيقي وتم منح درجة الماجستير بعلوم و هندسة المواد بتفوق

جامعـــة الإمـــارات العربيـــة المتحـــدة

عمـــادة الدراســـات العليـــا

برنامـــج علـــوم وهندســـة المـــــــواد

الدهانات وتأثيراتها البيئية على صحة الإنسان بدولة الإمارات

إعـــداد

المهندسة / مسرة يحيى العامري

رسالـــة مقدمـــة لعمـــادة الدراســـات العليـــا

ضمن متطلبات الحصول على درجة الماجستيـــر

فـــي علـــوم وهندســـة المـــواد

مشرف البحث الرئيسي : اد. محمود حجاج

قسم الهندسة المعمارية

جامعة الإمارات العربية المتحدة

يونيو 2003